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16. ABSTRACT

An atmospheric sampling program was carried out in the greater Phoenix, Arizona metropolitan area in November, 1975. Objectives of the study were to measure aerosol mass flux through Phoenix and to characterize the aerosol according to particle type and size. The ultimate goal of the study was to determine whether the high mass loadings of suspended particles recorded for Phoenix are due to human activities within the Phoenix area or to long range transport from the surrounding deserts.

Microscopic and chemical analyses of collected aerosol samples determined that minerals are the primary components of the Phoenix aerosol. The three mineral types that compose the bulk of the mass are the primary soil components in and around Phoenix and are also the primary components of the aggregate in the asphalt streets in Phoenix. Automobile-related particles ranged from 5% of the sample mass in outlying areas to as much as 50% in the central city on some sampling dates. These particles consisted of tailpipe emissions and rubber tire fragments and correlated with the presence of lead and bromine in the samples. The highest concentrations of automobile-related particles were found in periods of inversion at night and in the morning.

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ABSTRACT

An atmospheric sampling program was carried out in the greater Phoenix, Arizona metropolitan area in November, 1975. Objectives of the study were to measure aerosol mass flux through Phoenix and to characterize the aerosol according to particle type and size. The ultimate goal of the study was to determine whether the high mass loadings of suspended particles recorded for Phoenix are due to human activities within the Phoenix area or to long range transport from the surrounding deserts.

The sampling program was designed to take advantage of normal wind flow patterns of Phoenix. Typical "night wind" (8 p.m. to noon) is a light -- 1 to 2 m/sec -- drainage wind from the east with inversion breaking up near noon. Typical day wind (noon to 8 p.m.) is a light drainage wind from the west, with well-mixed conditions due to solar heating. Six tower sampling sites (three along the eastern rural edge of Phoenix and three along the western rural edge) and nine existing Maricopa County ground-level sites (located across the entire Phoenix valley) were employed to collect and measure aerosols entering and exiting the Phoenix area. In addition, a helicopter-borne sampler collected aerosols on the eastern and western edges of the metropolitan area during flight runs perpendicular to the wind flow. By choosing two sampling periods during "day wind" conditions (Nov. 17 and 18, noon to 6 p.m.) and two sampling periods during "night wind" conditions (Nov. 21 and 25, 6 a.m. to noon), it was possible to determine whether the bulk of the suspended particulate mass originated within or outside of Phoenix.

Particulate mass concentrations showed a mean value of 203 $\mu g/m^3$ in the area around Phoenix, except for Chandler which averaged 431 $\mu g/m^3$. The Central Phoenix sites averaged 210 $\mu g/m^3$. The mass concentration up to 20 m height was generally 50% higher downwind, although this trend was

obscured by the consistently higher concentrations at Chandler. The mass flux was generally in the range 0.1 to 0.2 mg/sec-m^2, except on one windy day (18 Nov.) when it reached 0.93 to 1.11 mg/sec-m^2. At heights above 20 m, the mass flux was always greater downwind than upwind by amounts of up to 50%. The mass concentrations measured spanned the size range from <1 μm to >25 μm in diameter. These data varied extensively with time, height, and location. Typical particle size mass distribution as determined by the Andersen samplers at 3 m height were:

Mass Distribution

Diameter Interval, μm:	0.9-2.5	2.5-8	8-15	15-25	>25
Concentration, μg/m^3:	15	40	30	30	30

During afternoon samplings, there was much greater vertical mixing than in the morning, as shown by wind profiles and temperature profiles, as well as higher particulate concentrations at heights of 200 to 500 m. Helicopter samples taken on these afternoons showed concentrations of 50 and 100 μg/m^3 up to 500 m height. Dust plumes from farm tractors could sometimes be seen mixing to heights of 100 to 200 m, and apparently they caused peaks in the helicopter nephelometer readings. Coarse particles (>15 μm) decreased in concentration by a factor of 2-3 with height from 3 to 30 m; fine particles showed considerable scatter, and apparently did not decrease in concentration with height up to 30 m.

Microscopic and elemental analyses of collected aerosol samples determined that minerals are the primary components of the Phoenix aerosol. Although as many as eight different mineral types were identified, the bulk of the mass was provided by three minerals -- quartz (alpha silica), feldspars (sodium, potassium and/or calcium — alumino silicates), and calcite (calcium carbonate). These three mineral types are the primary soil components in and around Phoenix and are also the primary components of the aggregate in the asphalt streets in Phoenix.

Automobile-related particles ranged from 5% of the sample mass in outlying areas to as much as 50% in the central city on some sampling dates. These particles consisted of tailpipe emissions and rubber tire fragments and correlated with the presence of lead and bromine in the samples. The highest concentrations of automobile-related particles were found in periods of inversion at night and in the morning. These periods were also characterized by high carbon monoxide levels, reaching 5 to 10 ppm. The carbon monoxide concentrations could be used to track the movement of an automobile-polluted air mass from the morning rush hour traffic. A visible layer of polluted air also correlated with the carbon monoxide readings and with helicopter nephelometer and hi-vol samplings.

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SECTION 1

INTRODUCTION

During the period 17 to 25 November 1975, an experimental program was carried out to measure the atmospheric particulate flux in Phoenix, Arizona. The objective of this study was to measure the aerosol mass flux, according to particle morphology, that enters and exits Phoenix during the period. These data will be used by the EPA to deduce the significant sources for total suspended particulates (TSP) in Phoenix.

The sampling plan consisted of sampling particulate matter in and around Phoenix using ground-, tower-, and helicopter-deployed samplers. Sampling within Phoenix made use of the existing hi-vol network operated by the Maricopa County Health Dept. Nine of these hi-vol sites were selected for the installation of additional samplers to obtain information about size and composition of atmospheric particulates. Additional samplers included low-volume fractionating samplers of the Battelle CS5 type, and dichotomous samplers provided by the EPA.

Data on particulate mass flux were obtained from samples taken both from a helicopter and from towers installed just outside the municipal area. The tower locations and the helicopter flight paths were chosen to sample the particulate matter carried by the wind flow through Phoenix. Previously defined flight paths were selected for each sampling period according to the weather reports and preliminary wind observations for each period.

Two tower sites used existing water towers, and the remaining four sites used rented towers 30 m high. Each tower was provided with a hi-vol sampler mounted at 3 m height, and three Andersen fractionating samplers mounted at 3, 10, and 30 m height. Battelle rather than Andersen fractionating samplers were employed at one tower site (Chandler).

During each sampling period, the wind field was measured by means of pilot balloons launched from as many as four sites. These wind data were combined with the particulate concentrations determined by the various samplers to calculate the mass flux.

This report presents all the available data from measurement of mass concentrations at all of the sites and summarizes the microscopic and elemental analyses. The average wind data are also presented in this report.

SECTION 2

CONCLUSIONS

Anthropogenic activity in the Phoenix area is the prime reason for the high total suspended particulate values for this area. Mass concentrations generally exceed 75 $\mu g/m^3$ both upwind and downwind of the city of Phoenix. Long-range transport of aerosols by winds from the surrounding deserts is only a minor source for suspended particles.

Wind activities do account for suspension of some of the more rounded, clay-coated minerals found in the samples. However, particle sizes and morphologies of the majority of the mineral particles found in all the Phoenix samples are not typical of wind-eroded materials. The wind activity maintains particles in a suspended state. Winds are generally not strong enough to blow the suspended particles clear of the Phoenix area; rather wind serves to move particles back and forth across the city, as wind direction reverses from day to night. Aerosol mass concentration flux data, as well as microscopic characterization of collected particles, support these conclusions.

At heights of 0 to 20 m, relatively local sources are responsible for suspended particulate levels recorded at specific sites. At height above 20 m, general human activities within the entire Phoenix area, rather than specific local sources, are primarily responsible for the suspended particulates present.

Mineral particles (quartz, calcite, mica, feldspars, clays) comprise 60 to 90 percent of the aerosol mass in the Phoenix area. These minerals are the primary soil components in Phoenix. Microscopic data support this conclusion.

Vehicular traffic (primarily automobiles), especially on unpaved roads and shoulders, is the primary generator of suspended particles. The appearance of smooth-surfaced, worm-shaped rubber tire particles, fine carbonaceous particles (tailpipe emissions), and clean-surfaces, sharp, angular mineral fragments indicate vehicle travel over paved roadways. This combination of particle types and morphologies was most frequently seen in samples from the central Phoenix area, as one might expect. Microscopic particle characterizations, x-ray fluorescence elemental analyses, carbon monoxide telemetry data, and mass concentration data support this conclusion.

Agriculture activity cannot be ruled out entirely as a source of suspended particles. Plowing, harrowing, and tractor movement over bare fields definitely generate suspendable particles. However, vehicular traffic is considered to be the more important source of suspended particles due to type and morphologies present in the samples. Agriculture related emissions - biological particles, fertilizer and pollens - represent only trace components on all samples, both on mass and number basis, while on the other hand, vehicular emissions - carbonaceous particles (tailpipes), rubber tire particles, and the shape of the mineral particles appeared more frequently in the samples. Combustion related emissions - flyash, charred paper and wood fragments, oil soot, and coal fragments - from sources such as incinerators, heating plants and power plants were found in only trace to minor components in some samples.

SECTION 3

RECOMMENDATIONS

The following recommendations are made for the analysis of the data in this report and for future measurements:

1. A comparison of the particle mass flux and composition should be made with the inventories of particulate sources in the area.

2. The sampling program should be repeated using a more consistent layout of the samplers. One objective should be to have as many of the same types of samplers as possible at all tower sites. Andersen samplers should be deployed at 3 and 30 m heights only, since the 10 m samplers gave little additional information. Dichotomous samplers should also be deployed at the tower sites to obtain samples for elemental analysis, and hi-vol samplers at 3 m as was done in this study to obtain most accurate mass concentrations. A larger vacuum hose should be used so that all Andersen samplers have the same air flow rate. A non-crystalline grease should be used on the Andersen sample foils.

   The county sites within the city should also be provided with Andersen samplers so that they can be compared with the tower sites. It would be preferable to operate fewer sites, each more fully instrumented with the same type of samplers.

   The helicopter sampler should be redesigned to achieve a 10-fold larger airflow for more accurate sample weights. Also, the sample holder should be redesigned to eliminate metal fragments from the holder and to eliminate damage to the filter in handling it under adverse conditions in the helicopter. Perhaps the filters can be premounted in holder rings.

3. Although the location of the samplers in the present study took reasonable account of the complex sources in the Phoenix area, it would be desirable to have a few samplers further upwind in another study. This could be done by reducing the number of tower sampling sites adjacent to the city to two on the east and two on the west. With more time available for preparation and setup, it should be possible to have all the samplers working reliably on all the sampling periods.

SECTION 4

SURVEY OF STUDY AREA

PHOENIX TERRAIN AND SAMPLING LOCATIONS

Figures 1 and 2 are Landsat photos of the Phoenix area taken 29 November 1974 using infrared band 7. Figure 2 is an enlargement of the outlined area in Figure 1. Vegetation appears white in this band; water is black. The city of Phoenix can be seen in the center of Figure 2, with the grid of main streets clearly visible. On the west is a large irrigated agricultural area, and another such area is southeast and east. UTM grid coordinates are marked on Figure 2. A picket fence of tower sampling sites was installed around the city in the agricultural green belts. On the west, tower sampling sites are at A, B, and C. (Detailed descriptions are given below.) On the east, the tower sites are at D, E, and F.

Also shown in Figure 2 are the numbered Maricopa County air quality sampling sites that were used on this project. Numbers 1 and 3 are in the central city, 2 is in the southern part of the city, 8 is in the eastern part in Scottsdale, 4 and 5 are in the western part, and 14 is in Paradise Valley, north of Phoenix. Depending on wind direction, some of these sites can be considered part of the picket fence, and others measure the air quality within the city itself. The tracks followed by the EPA helicopter during its air sampling flights are marked on Figure 2. Tracks upwind and downwind of the city were flown at heights from 30 m to 600 m. Tracks on the west are 1, 2, and 3. On the east is Track 11, on the north is Track 10, northeast is Track 14, and south is Track 4.

Figure 2 also shows the location of pilot balloon sites, at which wind measurements were taken. Site 1 was at the center of the city, Site A was on the northwest, Site x was at Goodyear on the southwest, and Sity y was on

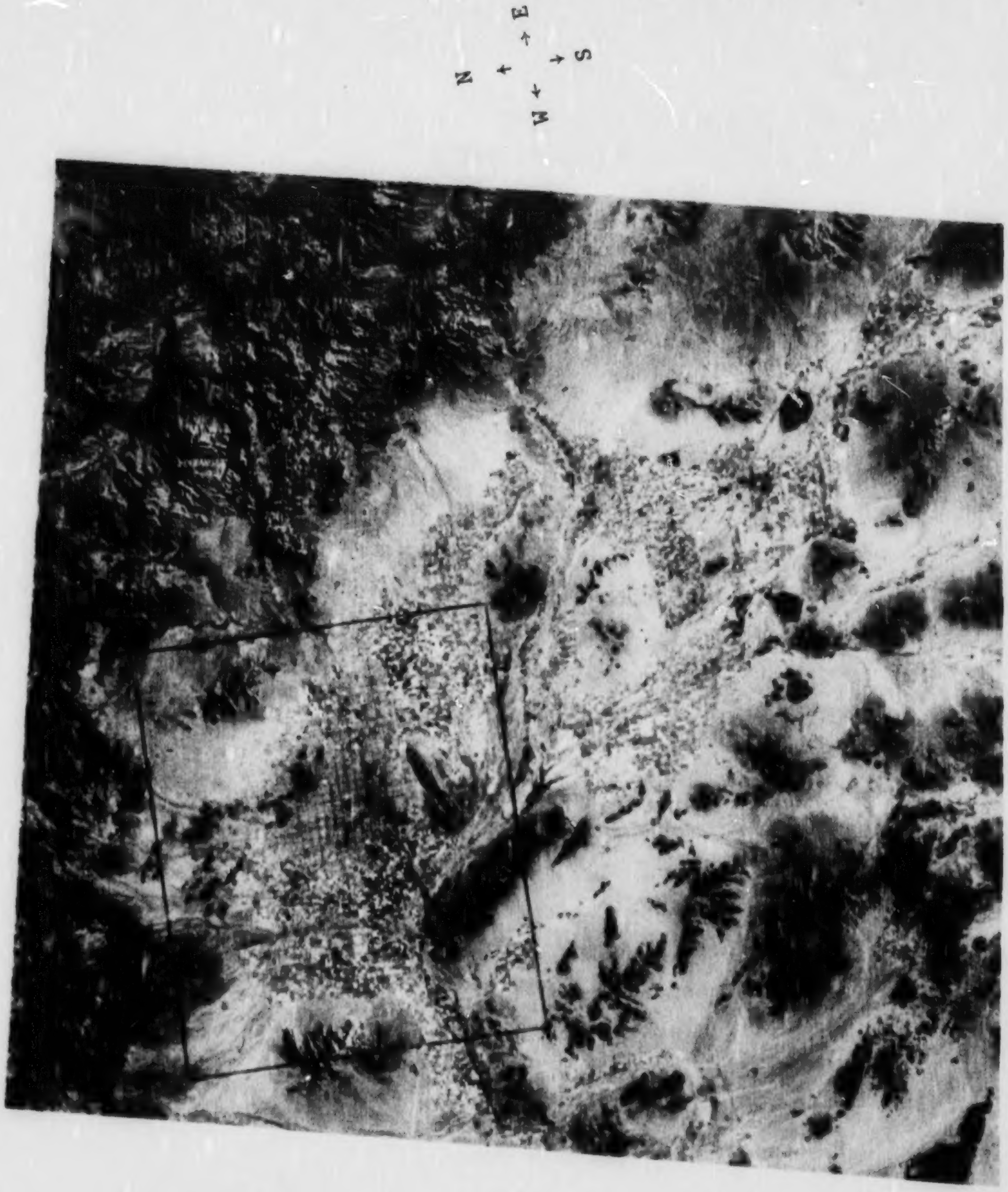

Figure 1. Landsat photo of South-Central Arizona, (Phoenix area boxed in).

KEY TO FIGURE 2

Pilot Balloon Sites

1	County Health Building
A	American Graduate School
x	Goodyear
y	Mesa

Tower Sampling Sites

A	American Graduate School
B	Parker Residence
C	Page Residence
D	Indian Reservation
E	Mesa
F	Chandler

County Sampling Sites

1	Central Phoenix (County Health Building)
2	South Phoenix
3	Arizona State Capitol
4	Glendale Community College
5	West Phoenix
8	Scottsdale Fire Station
14	Paradise Valley Pump Station
E	Mesa (County Site #9)
F	Chandler (County Site #16)

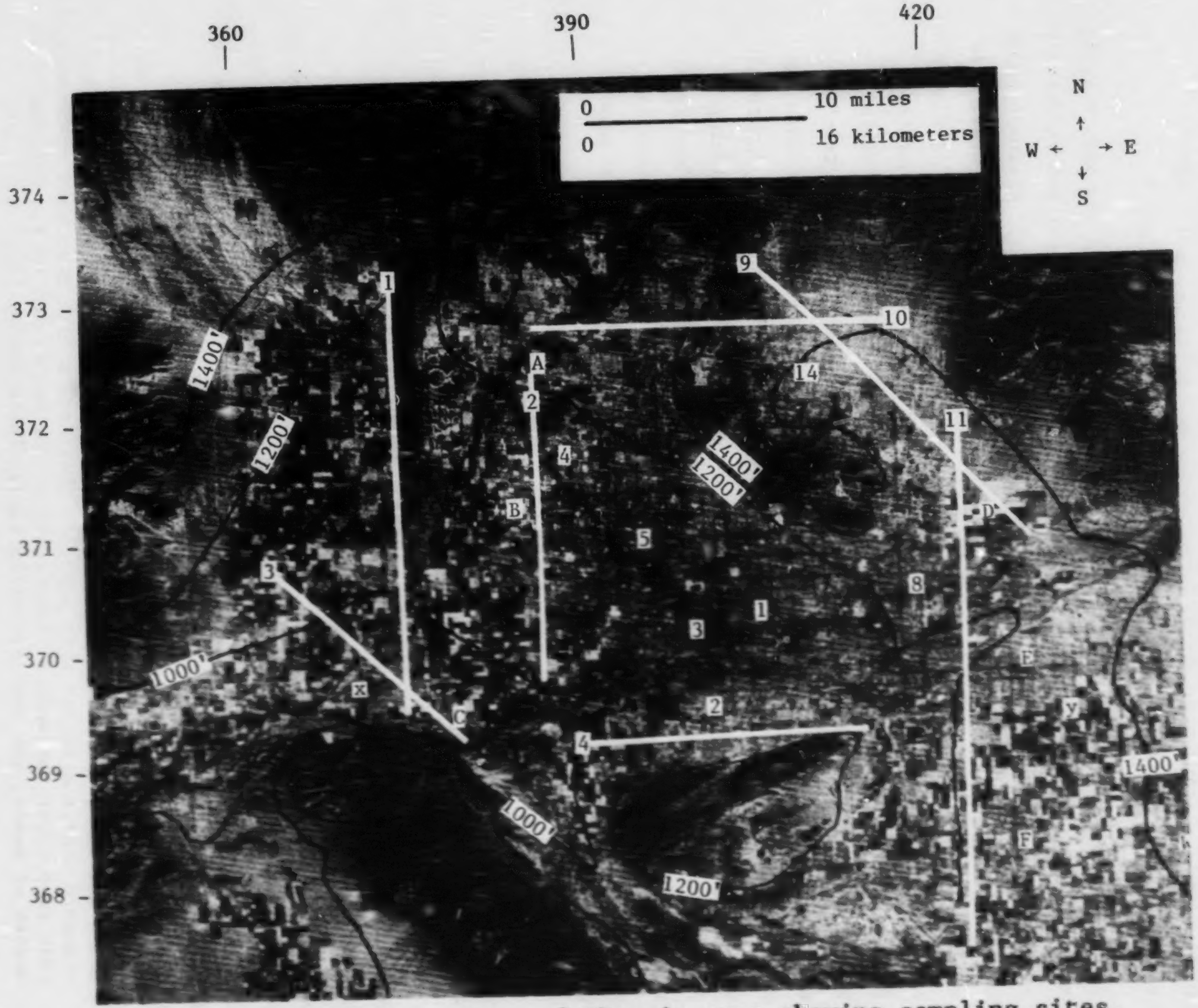
360
390
420
374
373
372
371
370
369
368
0 10 miles
0 16 kilometers
N
W
E
S
1400'
1200'
1000'
1
2
3
4
5
8
9
10
11
14
A
B
C
D
E
F
x
y

Figure 2. Landsat photo of Phoenix area showing sampling sites.

the east, just southeast of Mesa. Also shown on the right-hand margin of Figure 2 is a W for Williams Air Force Base, where some additional samplers were installed. The contour lines for 1,000 ft, 1,200 ft, and 1,400 ft elevations are outlined and marked with the respective altitudes.[1]

This Landsat photo not only shows the municipal area and the agricultural greenbelt, but it also shows the location of the mountains that hem in Phoenix and affect the wind patterns. The whole area forms a large air drainage basin, with a gentle slope following the rivers down from the east to the west. The drainage funnels between the White Tank Mountains on the west edge of Figure 2 and the Sierra Estrella, which is the rugged mountain range just south of Site C. Within Phoenix, the drainage is fan-shaped, flowing down the Salt River bed from Mesa to Site C, and down from the Phoenix mountains in the northeast toward Site C. On the west side, the drainage wind flows down the bed of the Agua Fria. These drainage wind directions are shown in Figures 3 and 4 (taken from N. S. Berman and K. B. de Laney, "Atmospheric Modeling for Phoenix, Arizona", Report ERC-R-75009, Arizona State Univ., Tempe, May 1975). The night winds (east to west flow) become evident at about 8 p.m. and last until early morning. The day winds (west to east flow) develop near noon and last until after sunset.

Some landmarks can be identified in the photo for orientation. Cutting diagonally through the city from Sites 4, 5, and 3 is Grand Ave., or Highway 60. Just to the east of Site 3 is a city grid that is bisected by Central Ave., the main north-south street. At the north end of Central Ave. is North Mountain; at its south end is South Mountain. Just south of Site 1 is Van Buren St., the main east-west street. Just east of Site 5 is Freeway 17, which runs north into the desert. Just west of Site 8 is Scottsdale Rd., which also runs north into the desert. Barely visible south of Track 10 is Bell Rd., the northern corporate limit of Phoenix. Just west of Track 11 can be seen the edge of the checkerboard pattern of irrigation in the Salt River Indian Reservation and the gray residential area of Scottsdale. Site E is in Mesa,

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[1] Since the units of foot and mile (English System of Units) were used on the standard charts used for this project, these units have been used throughout this report for the sake of consistency. For conversion to the International System of Units, see the conversion table (Table Number 52).

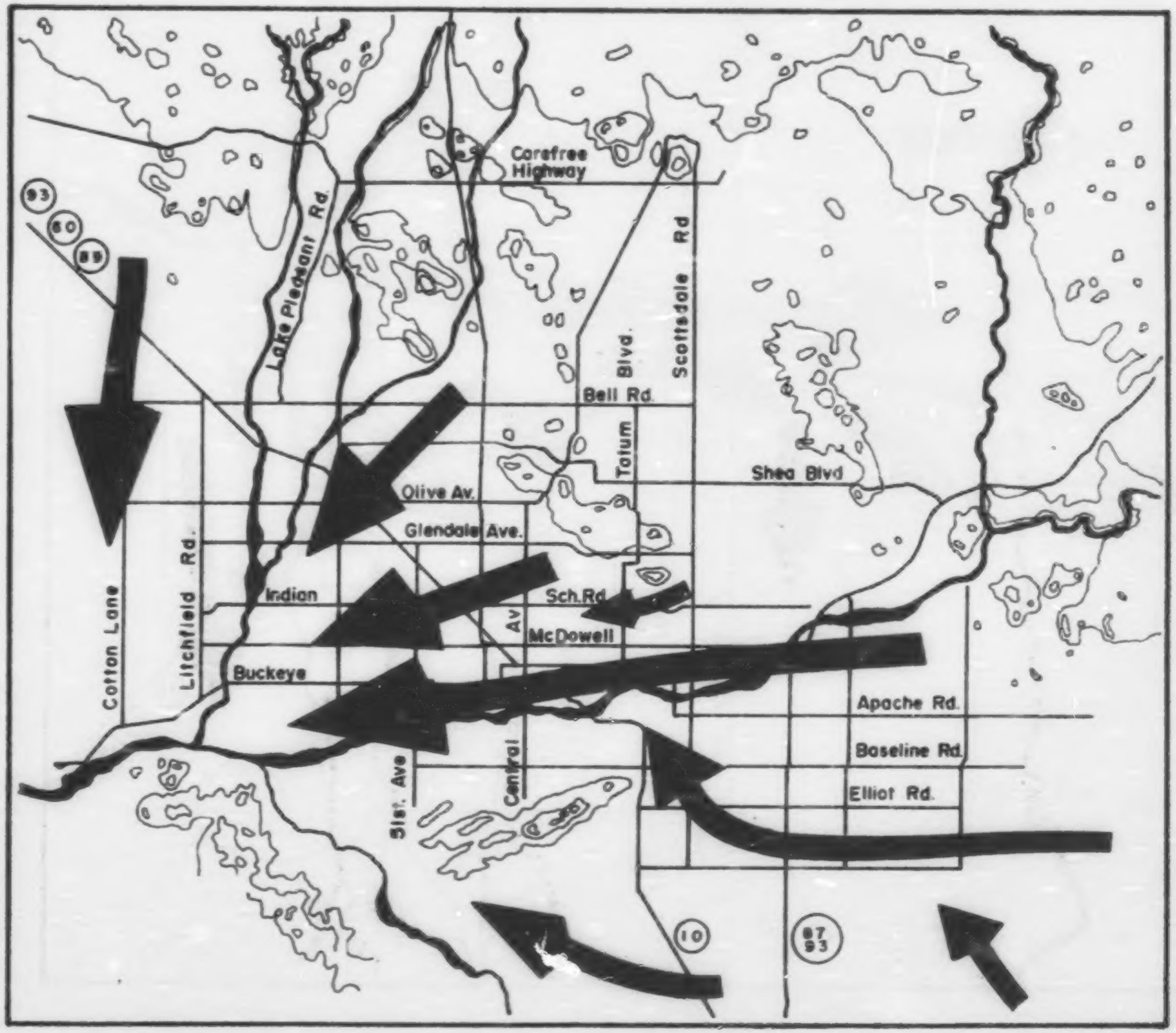
93
60
89
Lake Pleasant Rd.
Carefree Highway
Scottsdale Rd
Blvd.
Bell Rd.
Tatum
Shea Blvd
Olive Av.
Glendale Ave.
Indian
Sch.Rd
Av
McDowell
Buckeye
Cotton Lane
Litchfield Rd.
Apache Rd.
Baseline Rd.
Elliot Rd.
51st. Ave
Central
10
87
93

Figure 3. Night Wind Trajectories.

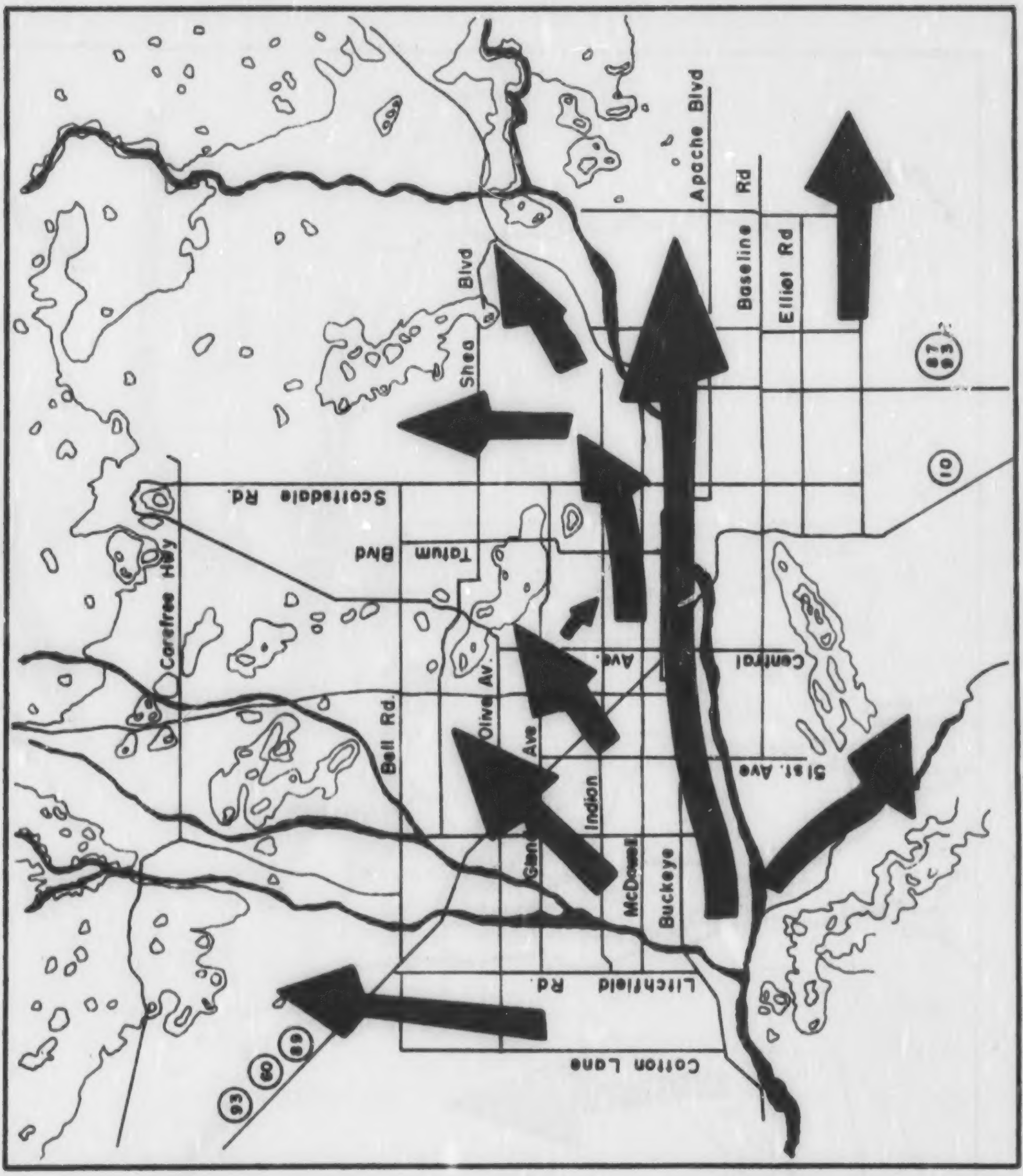
Apache Blvd
Baseline Rd
Elliot Rd
87
93
Shea Blvd
10
Scottsdale Rd.
Tatum Blvd
Carefree Hwy
Central
Ave.
Bell Rd.
Olive Av.
Glen
Ave
51st. Ave
Indian
McDowell
Buckeye
Litchfield Rd.
Cotton Lane
93
60
89

Figure 4. Day Wind Trajectories.

a city of 100,000 population. Just south of Site E is Highway 60, which runs through Tempe and Mesa to the east. Site x is just south of the town of Goodyear on the west side of the photo. North of Site x can be seen the trace of Highway 80 on the west, and the runway of Phoenix-Litchfield Airport at Goodyear. Northeast of Track 3 can be seen the runways of Litchfield Air Force Base. Several dry river beds can also be seen. Just east of Track 1 is the dry Agua Fria riverbed running north-south. It is tributary to the Gila River, which enters from the south at Site C between two mountain ranges and flows to the west, south of Goodyear. The Salt River enters from the east side of the photo, just north of Mesa, flows across the southern part of Phoenix between Sites 2 and 3, and joins the Gila River just south of Site C. Just east of Site C can be seen the black track of water in the Salt River. Also visible on the photo are some irrigation canals. The Arizona Canal is a thin, black track that runs just north of Site D in the Indian Reservation, curves in an arc around the southeast edge of the Phoenix mountains, and runs off toward Site A in the northwest part of Phoenix.

DESCRIPTION OF TOWER SAMPLING SITES

The sampling towers were located in green areas outside the city. Unpaved dirt roads were avoided. The following descriptions note any nearby possible sources of dust.

American Graduate School
Greenway Road & 59th Avenue, Glendale

A 30 m sampling tower was installed on the grounds of the American Graduate School for Foreign Management. The tower was located 100 ft from a yard to the southeast which is unpaved and has occasional car and truck traffic, and 50 ft from Greenway Road to the north which is paved but has a wide unpaved shoulder. Sometimes dust was observed when cars drive on the shoulder. To the northeast is a sparse residential area on the desert, and to the west are agricultural fields. No agricultural activity was noted during the sampling period.

Parker Residence
83rd Avenue north of Bethany Home Road

A 30 m sampling tower was installed in a grassy field near the house, 150 ft east of 83rd Ave. An unpaved driveway was on the other side of the house. 83rd Ave. has unpaved shoulders. To the west was a cotton field.

There was no agricultural activity nearby during the period, except for a few grazing cattle.

Page Residence
102nd Avenue & Southern Avenue

A 30 m sampling tower was installed in a grassy field 150 ft east of the house, 100 ft north of Southern Ave. Southern Ave. has unpaved shoulders. No nearby agricultural activity was noted during the period.

Indian Reservation
Alma School Road & Chapparal Avenue

This site is located about 2 miles east of the boundary of Scottsdale, 1/2 mile from the northeast edge of the irrigated farm region of the Salt River Indian Tribe. A 30 m tower was installed inside a fenced storage area, about 100 ft east of a water tank that is 8 m high. This fenced area was surrounded by cotton fields, but there was minimal agricultural activity during the period. The fenced area is unpaved, but we observed only occasional traffic within the area. The nearby roads have unpaved shoulders. One mile west of the site is a 1/2 mile section of Chapparal Rd. that is unpaved. Large quantities of dust were observed to be generated by traffic on this section of road, and they could have reached the tower when wind was from the west.

Mesa Water Tower
3rd Place & Center Avenue, Mesa

A fenced area contains the existing County sampling equipment and a large water tower that was used on which to mount samplers. The site is unpaved, but had no internal traffic. To the southeast is a city park, and the area to the west is grassy residential. To the north is a fenced area containing municipal maintenance buildings and a recycling center with an unpaved parking area. The site is near the center of a city of 100,000 population, close to the intersection of University and Center.

Chandler Water Tower
East Chicago Avenue & Delaware Street

A fenced area contains the municipal maintenance yard and two water towers. Our samplers were mounted on one tower. The yard is unpaved and had some truck traffic. The site is on the southeast edge of Chandler.

The area to the north and west is residential. The area to the southeast is agricultural, including a small feedlot 1/2 mile away. Adjacent to the tower in this direction is a small railroad yard that had little observed activity, although it is unpaved.

DESCRIPTION OF COUNTY SAMPLING SITES

Some of the sites used are existing sites of the Maricopa County Health Dept. and were used with their kind cooperation.

Central Phoenix
1825 East Roosevelt, Phoenix

This site is on the roof of the County Health Building, height 10 m. To the east is a city park, to the west a paved parking lot, and the surroundings are residential. Streets are paved to the curb.

South Phoenix
4732 South Central Avenue, Phoenix

This site is on the roof of project LEAP building, height 10 m. The surrounding area is commercial. It is at an elevation of 1,205 ft on the slope leading to South Mountain.

Arizona State Capitol
1740 West Adams Street, Phoenix

The site is on the roof of a one-story building in the State Capitol area, height about 7 m. Although the immediate surroundings are grassy, the site is surrounded by an industrial or commercial area.

Glendale Community College
6000 West Olive Street, Glendale

This site is on the roof of a college building, height 8 m. It is on the north edge of the City of Glendale in a residential area.

West Phoenix
Grand Canyon College, 3300 West Camelback, Phoenix

The samplers are mounted above the ground on the college campus. The samplers are completely surrounded by wooden buildings forming a small square. The site is located east of the busy Grand Ave. and west of Freeway 17. It is also east of a very large unpaved railroad yard that parallels Grand Ave.

Scottsdale
2857 North Miller Road, Scottsdale

The site is on the roof of the fire station, height 8 m. It is surrounded by a grassy residential area. It is about 2 miles west of the boundary of the Indian Reservation agricultural area.

Mesa (E on Figure 2)
3rd Place and Center Avenue, Mesa

This is the same site previously described under Tower E. The County samplers are mounted on legs at 1.5 m height above a small cement pad in an unpaved, fenced lot next to a small building.

Paradise Valley Pumping Station
3546 East Sweetwater Road, Phoenix

The pumping station is a fenced area containing a large water tank about 8 m high. The sampler is mounted at 2 m height. The lot is unpaved, as is the surrounding terrain. It is 30 m west of an unpaved side road, and 1/4 mile north of an unpaved main road. In the late afternoon of 19 November, a low-lying inversion layer was seen to contain visible dust covering the whole Paradise Valley area. The dust was observed to be generated by automobile traffic on unpaved roads.

Chandler Police Building (F on Figure 2)
250 East Commonwealth Avenue

This site is located two blocks north of the Chandler tower Site F. The sampler is on the roof at 10 m height. The area to the west is residential, and to the east are agricultural fields. No nearby agricultural activity was observed during the period.

SECTION 5

SAMPLING AND ANALYSIS METHODS

SAMPLING STRATEGIES

The four types of stationary (ground-based) particle samplers employed in the study were operated for six hours on each of the five sampling days. Sampling time periods were chosen to take advantage of the wind flow patterns of Phoenix. Two sampling days were chosen to place sampling sites on the western edge of Phoenix downwind of the city's activities -- i.e., night wind patterns (6 a.m. to noon). Two sampling days were chosen to place eastern sampling sites downwind of Phoenix -- i.e., daywind patterns (noon to 6 p.m.). By comparing particle types at the individual sites from day to day, it was possible to determine whether atmospheric particle concentrations were due mainly to localized sources or wind transport of particles from long-range sources. A fifth sampling period was chosen during late night hours (10 p.m. to 6 a.m.) to determine if particle sources other than those seen in day and early evening hours were contributing to the high TSP levels in Phoenix.

A helicopter-borne particle sampler performed sampling during the same time periods in which the ground-based samplers were operating. In addition, the helicopter performed sampling on one day during which no ground-based samplers were operating. Helicopter runs were made in tracks upwind and downwind of the city, perpendicular to the wind direction.

Sections 6 through 11 of this report contain the sampling conditions and analyses data for each of the six sampling periods.

SAMPLER TYPES

Due to the limited numbers of the various types of samplers available for use in the study and occasional equipment failures, different stationary sampler types were operated at different sites during the five sampling days. Table 1 indicates the types of samplers operated at each site for each date. Descriptions of the four ground-based particle sampler types and the helicopter-borne particle sampler are given below.

High Volume (Hi-Vol) Samplers

The standard EPA high volume samplers were deployed at most of the sampling sites each day. A sampler consists of a tared, 8-inch by 10-inch glass fiber filter through which ambient air is drawn by a vacuum pump. The sampler is mounted in a protective housing. Flow rates through each sampler were measured and reported in IITRI Report C6333C05-1.

Andersen Samplers

The standard seven stage (eight stages including the back-up filter) Andersen size fractionating impactors deployed at the tower sampling sites were slightly modified for this study. Three stages (numbers 1, 3, and 5 in most cases) were eliminated to permit collection of weighable masses of particles during the relatively short sampling time periods.

Three types of collection substrates were used. Stages 0 and 2 used 90 mm diameter greased (Apiezon brand) aluminum foil discs. Stages 4 and 6 used ungreased aluminum foil discs. The final back-up filter was a cellulose ester membrane filter (Millipore brand). Air flow rates through the individual Andersen samplers varied; thus, particle diameter cut-off size for each stage varied from sampler to sampler. These cut-off sizes were determined for each sampler and were reported in IITRI Report C6333C05-1.

Battelle Samplers

Low-volume, size fractionating, single jet impactors, developed by Battelle Labs, were employed at some tower and county sampling sites on some sampling days. In most instances, the samplers were used as designed -- five impaction stages with a final back-up filter as a sixth stage. However, at some sites, two additional stages -- 00 and 0 -- were added to provide further size separation of the larger particles.

Collection substrates again varied from stage to stage. Stages 00, 0, 1, and 2 were greased (Apiezon brand) one-inch diameter glass discs. Stages 3,

TABLE 1. OPERATIONAL SAMPLERS

Sites	17 Nov.				18 Nov.				21 Nov.				23-24 Nov.				25 Nov.			
									Sampler Types*											
	HV	AN	BT	DI	HV	AN	BT	DI	HV	AN	BT	DI	HV	AN	BT	DI	HV	AN	BT	DI
West																				
A. Amer. Grad. Sch.	✓	✓			✓	✓			✓		✓		✓	✓			✓	✓		
B. Parker Res.	✓	✓			✓	✓			✓	✓			✓	✓			✓	✓		
C. Page Res.									✓	✓			✓	✓			✓	✓		
5. West Phoenix	✓		✓	✓	✓			✓	✓			✓	✓			✓	✓			✓
4. Glendale Coll.									✓		✓		✓		✓		✓		✓	
East																				
D. Indian Resv.	✓		✓						✓	✓			✓	✓			✓	✓		
E. Mesa (Tower)		✓**							✓	✓			✓	✓			✓	✓		
9. Mesa (County)	✓		✓	✓	✓			✓	✓			✓	✓			✓				✓
F. Chandler (Tower)	✓		✓		✓		✓		✓	✓			✓		✓		✓		✓	
16. Chandler (County)	✓		✓	✓	✓			✓	✓			✓	✓			✓	✓			✓
8. Scottsdale	✓		✓	✓	✓			✓	✓				✓			✓	✓			✓
14. Paradise Valley									✓		✓		✓		✓		✓		✓	
Central																				
1. Central Phoenix	✓				✓				✓			✓	✓			✓	✓			
2. South Phoenix	✓			✓	✓			✓	✓			✓	✓			✓	✓			✓
3. Arizona Capitol									✓		✓		✓		✓		✓		✓	

* HV = Hi-Vol
AN = Andersen
BT = Battelle
DI = Dichotomous

** All of the three samplers did not operate.

4 and 5 were ungreased, one-inch glass discs. A polycarbonate (Nuclepore brand) membrane served as the final back-up filter.

Air flow through the samplers was restricted by a critical orifice to 1.05 ℓ/min. Cut-off sizes for each stage at this flow rate were 16, 8, 4, 2, 1, 0.5, and 0.25 μm for stages 00, 0, 1, 2, 3, 4, and 5, respectively.

Dichotomous Samplers

This sampler uses the principle of virtual impaction to fractionate the aerosol. Particles with a mean diameter greater than 3.5 μm (coarse fraction) and less than 3.5 μm (fine fraction) are collected on separate 37 mm diameter Teflon filters, and subsequently analyzed by X-ray fluorescence spectrometry. Quartz fiber filters are used to collect a total, unfractionated sample.

Six of these samplers were available for this study. Most of these samplers were deployed at county sampling sites.

Helicopter-borne Samplers

A modified sampling head designed for attachment to a standard hi-vol vacuum pump was developed by EPA personnel. The sampling head, which held a tared, 4-inch diameter glass fiber filter disk, was mounted on a rack on the side of the EPA helicopter. The rack pivoted so that it could be swung outside the helicopter boundary layer during sampling.

MASS CONCENTRATION DETERMINATIONS

Mass concentration data for TSP, expressed as $\mu g/m^3$, are given in tables in Sections 6 through 11 for the various types of samplers used. Methods of determining the data are described below, according to sampler type.

Hi-Volume Samplers

Although sampling time periods were short, weighable masses of particles were collected on the glass fiber filters. From the weighed mass and known sampling rate and period of time, mass concentration was calculated.

Andersen Samplers

In most instances, weighable masses of particles were collected on each stage; therefore, mass concentrations in each particle size fraction were calculated. Minimum mass loadings onthe final back-up filters were determined by X-ray fluorescence analysis.

Battelle Samplers

Sufficient masses of particles were not collected on any of the sampler stages for gravimetric determination. Therefore, no mass concentration data was available for samples collected by this type of impactor.

Dichotomous Samplers

Mass determinations on the coarse and fine stage samples were made by gravimetric analysis.

Helicopter-borne Samplers

Although weighable particle masses were collected on many of the filter samples, the appearance of torn filter edges, metal fragments, and negative masses for some filters rendered many of the gravimetric determinations unreliable. All samples were examined by optical microscopy; estimates of mass loading on samples with unreliable gravimetric mass determinations were made by microscopic observation of numbers of particles present and particle size. If microscopic mass estimates had not been performed, there would have been insufficient data to calculate mass flux at heights above 30 m.

MICROSCOPIC PARTICLE CHARACTERIZATION

The majority of the particle samples collected in the study were submitted for microscopical analysis. The purpose of the microscopical analysis was to identify the particles and, where possible, relate particles to sources. Both optical and scanning electron microscopy were employed for identification.

Particle samples collected on glass fiber filters (hi-vol and helicopter samples) were prepared for optical microscopic analysis by immersing small, wedge-shaped sections cut from the filters in an organic liquid with a refractive index which matched the refractive index of the glass fibers (1.546). The glass fibers were thus rendered invisible, and the deposited particles were easily viewed by polarized light microscopy. A cover glass was placed on the immersed section to complete the mounting.

The first four stages (00, 0, 1, and 2) of the Battelle impactor samples were coated with (Apiezon brand) grease. The grease is crystalline, which interferes with particle analysis by polarized light microscopy. These samples were warmed on a hot plate to melt the grease and eliminate the interference. Final stages 3, 4, and 5 were not coated with grease and could be examined without warming. The final polycarbonate membrane (Nuclepore brand) filter was analyzed only by scanning electron microscopy.

Hi-vol sections were prepared for scanning electron microscopy by carbon coating the specimens to minimize charging effects.

Each of these sample preparation techniques preserves the samples as collected and minimizes alterations in morphology and particle size. Aerosols collected by the Andersen impactors were submitted for microscopic analysis but could not be examined microscopically because they were collected on greased, aluminum foil. Attempts to remove the particles from the foil substrate were unsuccessful. Results of the microscopic analyses are described in Sections 6 through 11.

ELEMENTAL ANALYSES

Samples not submitted for microscopic analysis -- Andersen final filters and the samples collected by the dichotomous samplers -- were analyzed by x-ray fluorescence techniques. These analyses were performed by EPA personnel at the U.S. EPA Environmental Sciences Research Laboratory. Results of these analyses are included in the following sections of this report.

WIND MEASUREMENTS

The wind vs. height was measured at up to four locations during each sampling period by observing the ascent of pilot balloons. The locations are shown in Figure 2. The resulting speeds and directions at each height were shown in Report C6333C05-1 (Data Report). Averages for each day are given in this report. These wind data were used to compute the mass flux during each sampling period.

The method of wind measurement was as follows. Each 30 minutes during the sampling period, a pilot balloon was released and tracked by a theodolite. The balloon was filled with helium until it would just lift a 30 g weight, and the weight was removed before release. At night, the balloon was fitted with a battery-operated light. The rate of ascent was known from previous calibrations, and so measurement at only one ground location was needed to determine the wind direction and speed. Azimuth and inclination angles were recorded each 30 sec, and the wind data were input to a computer program that calculates the wind speed and direction. Each data point represents the average within a 200 m range of elevation centered on the height given; e.g., the values at 50 m represent the average from 0 to 100 m.

In the following sections, tables are given showing the average wind profile at each site, and also the average over all the sites for each day. The averaging was done by computer. A vector average speed and direction was computed by resolving each wind profile into speed components in the x- and y-directions, and summing these algebraically. The resultant direction was then computed from tan (y/x), and the vector average speed (root-mean-square) was computed. The arithmetic average speed was also computed. It was not used in the mass flux calculations. It is generally higher than the vector average because it does not take into account the effect of varying wind direction, both at different times and different sites. It shows the largest difference from the vector average on days when the wind direction was variable, such as 25 November.

On days when the sampling period did not coincide exactly with the duration of the drainage wind, a few wind measurements toward the end of the sampling period were excluded from the average. This was done so that the average wind profile would not be influenced by a brief period when the drainage wind had turned around. The actual time period included in the average is denoted on the wind profile tables.

Since the particulate concentration varies rapidly within the first 100 m, it is desirable to have additional data on winds at ground level. Available cup-anemometer readings from the Maricopa County Health Dept. monitoring stations are accurate to ± 1 m/sec only during winds greater than 2 m/sec. Since these ground wind measurements did not help during periods of light winds, they were not included in this report.

At one site (Goodyear), surface winds were measured by taking an initial sighting of the balloon. These surface winds are recorded on the tables in Report C6333C05-1, and the average is given in this report.

SECTION 6

FIRST SAMPLING PERIOD - MONDAY, 17 NOV. 1975, NOON TO 6:00 P.M.

MASS FLUX DETERMINATIONS

The wind profiles in Tables 2 and 3 are averages for the afternoon after 1300 hrs. Drainage wind is usually from east in the morning and west in the afternoon. Sampling began at noon, but the drainage wind did not turn around until 1300 hrs; in the first 100 m the drainage wind was 1 m/sec from 90° until 1300 hrs. At heights above 800 m there was a steady synoptic wind of 3 m/sec from 240° (SW). This penetrated to the surface after 1330 hrs, since it was in the same direction as the afternoon drainage wind.

Temperature data in Figure 5 show isothermal (mixed) conditions to heights of 250 m at 1220 hrs. At 1512 hrs the first 80 m showed surface heating.

The helicopter data are presented in Table 4. These data also indicate well-mixed conditions upwind, to 300 m height. The nephelometer trace shows peaks that can be associated with agricultural dust plumes. Downwind, the average concentration is higher, and decreases with height. The nephelometer shows the opposite trend with height. The nephelometer is sensitive to particles of size near the wavelength of light, and apparently it shows that a plume of these fine particles mixes to at least 300 m height downwind of the city. The coarser particles measured by the filter mass decrease with height because of settling.

Table 5 summarizes the mass concentrations measured by both ground and tower samplers and the helicopters. The concentrations for each height measured by each method are averaged in Table 6 and multiplied by the wind speed to compute the mass flux per m^2 of air flow entering and leaving the city. The data in the last column show that there is no measurable change

TABLE 2. AVERAGE WIND PROFILE FOR 17 NOVEMBER, 1975
1300 to 1730 Hrs

Vector Average			Arithmetic Average
Height m	Speed m/sec	Direction Degrees	Speed m/sec
50	1.1	243.4	1.5
100	1.4	240.4	1.9
150	1.2	233.9	1.8
200	1.2	230.8	1.7
250	1.2	230.5	1.8
300	1.4	229.4	1.9
350	1.5	228.6	1.9
400	1.8	229.3	2.1
450	2.0	230.4	2.4
500	2.4	229.5	2.7
550	2.7	228.6	3.1
600	3.1	229.4	3.4
650	3.4	230.7	3.6
700	3.7	231.3	3.8
750	3.9	231.0	4.1
800	4.2	232.0	4.3
850	4.5	233.2	4.6
900	4.8	231.1	4.9
950	5.2	229.1	5.3
1000	5.5	227.5	5.5
1050	5.8	226.2	5.8
1100	6.1	225.5	6.2
1150	6.4	225.0	6.5
1200	6.8	224.5	6.9
1250	7.0	222.6	7.1
1300	7.3	220.2	7.4
1350	7.4	218.5	7.6
1400	7.6	216.9	7.7
1450	7.7	215.5	7.9
1500	7.9	214.5	8.1
1550	8.2	212.1	8.6
1600	8.3	211.2	8.7
1650	8.5	212.0	8.7
1700	8.8	211.3	9.0
1750	9.2	210.1	9.4
1800	9.5	209.3	9.7
1850	9.7	209.7	9.9
1900	10.1	209.6	10.2
1950	10.9	211.4	11.1
2000	10.9	210.2	11.2

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TABLE 3. WIND PROFILES AT PILOT BALLOON SITES FOR 17 NOVEMBER, 1975
Vector Averages

	Central		Goodyear		Grad School	
Height m	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees
50	1.2	289.3	.8	261.2	2.0	212.2
100	1.6	290.5	1.0	248.8	2.4	208.6
150	1.5	295.5	1.1	230.1	2.1	202.4
200	1.3	294.8	1.4	229.7	1.8	198.7
250	1.2	293.5	1.8	233.0	1.7	193.2
300	1.2	288.6	2.0	231.9	1.6	195.6
350	1.1	277.0	2.2	231.9	1.5	199.5
400	1.7	256.5	2.5	234.0	2.0	202.4
450	1.4	260.6	2.9	237.2	2.2	204.8
500	1.6	252.9	3.2	237.8	2.7	206.3
550	1.9	248.7	3.5	237.4	3.0	207.9
600	2.4	246.4	3.7	233.9	3.4	213.6
650	2.8	247.9	3.8	229.2	3.7	220.6
700	3.2	246.1	4.0	228.5	3.9	222.5
750	3.6	243.9	4.1	228.6	4.1	222.7
800	4.0	242.5	4.4	228.9	4.3	225.9
850	4.4	241.4	4.7	229.2	4.3	229.6
900	4.8	239.5	5.1	226.3	4.7	228.0
950	5.2	237.6	5.5	225.7	5.0	226.5
1000	5.4	233.6	6.0	222.5	5.1	226.8
1050	5.8	229.6	6.4	222.1	5.2	227.5
1100	6.2	225.4	6.8	223.2	5.4	226.3
1150	6.6	223.8	7.1	223.7	5.7	227.6
1200	7.0	224.3	7.4	223.6	6.0	225.7
1250	7.1	221.2	7.7	223.5	6.4	223.2
1300	7.2	216.7	8.0	223.0	6.8	220.7
1350	7.3	214.9	8.3	221.5	6.8	218.7
1400	7.4	213.4	8.6	220.0	6.9	216.7
1450	7.4	211.7	8.9	219.0	7.1	215.2
1500	7.5	208.6	9.1	218.2	7.1	216.0
1550	7.9	202.6	9.4	217.7	7.6	215.1
1600	8.1	202.3	9.2	216.8	8.0	214.5
1650	8.2	206.6	9.3	215.4	8.2	213.9
1700	8.4	206.2	9.5	214.1	8.7	213.6
1750	8.8	204.0	9.9	212.8	9.2	213.5
1800	8.8	203.8	10.2	211.6	9.6	212.5
1850	8.8	205.3	10.5	210.8	9.9	212.5
1900	9.5	204.7	10.8	211.4	10.0	212.2
1950	.0	.0	10.9	211.4	.0	.0
2000	.0	.0	10.9	210.2	.0	.0

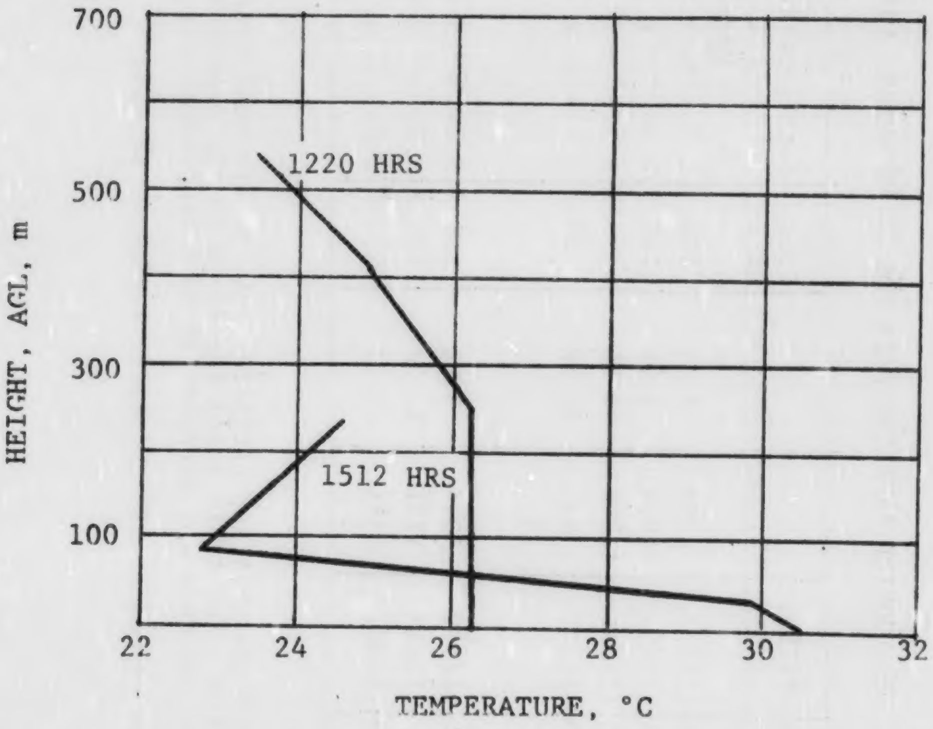

Figure 5. Height vs. Temperature, 17 November, 1975.

TABLE 4. HELICOPTER SAMPLING DATA FOR 17 NOVEMBER, 1975

Track	Time, Min Start	Time, Min Δ	Altitude ft	Altitude m	Filter No.	Wt, µg	Flow, m^3	Conc, $\mu g/m^3$	Nephelometer, Volts** (Position in Track) N — Midpoint — S	Average
West - Upwind										
1	1518	12	1000	305	117536	783	7.47	104.8	1.7 ∿ 2.5 ∼ 2.3	2.2
1	1537	16	500	150	117533	(1000)	9.96	(100.)	2.4 ∼ 2.5* ∼ 1.8	2.2
1	1555	17	100	30	117546	(1000)	10.58	(95.)	2.3 ∿ 1.7 ∼ 2.0	2.0
1	1615	17	100	30	117548	991	10.58	93.7	2.3 ∼ 2.3 ∼ 1.9	2.2
East - Downwind										
11	1241	16	1000	305	117539	1015	9.96	101.9	3.0 ∿∿ 2.0 ∿ 1.0	2.0
11	1305	18	500	150	117545	1251	11.21	111.6	3.0 — 2.0 ∼ 1.3	2.1
11	1328	18	100	30	117547	1386	11.21	123.6	2.0 — 1.5 — 1.0	1.5

*Plowing

**The nephelometer responds to µm-sized particles, not to the full range of sizes collected by the samplers. The table shows the shape of the nephelometer trace and the average readings at ends and midpoint of each helicopter run.

( )Numbers in parentheses represent microscopical estimates of mass

TABLE 5. MASS CONCENTRATIONS FOR 17 NOVEMBER, 1975

		Mass Concentrations, µg/m³												
		Hi-vol		Andersen*						Dichotomous*		Hi-vol (Microscope Est.)**		
	Height m	Tower	County	>25 µm	>15 µm	>8 µm	>2.5 µm	>0.9 µm	Sum	Fine <3.5µm	Coarse >3.5µm	>15 µm	5-15 µm	<5 µm
Upwind														
A. Am. Grad. School	3	216.			98.9	70.4	18.1	4.9	192.			108.	86.	22.
	10				45.6	10.5	3.5	2.6	62.					
	30				23.2	21.2	24.4	7.8	77.					
B. Parker	3	214.		77.4	--	64.8	26.8	5.4	174.					
	10			27.9	--	27.8	130.	9.6	195.					
	30			0	--	15.2	17.3	0	33.					
5. West Phoenix	6		239.							72.	132.			
Helicopter 1600 hrs	30	(95.)												
	30	93.7												
	150	(100.)												
	305	104.8												
Downwind														
D. Indian Res.	3	407.										203.	163.	41.
E. Mesa	3		157.							66.	129.			
	30			40.4	—	34.9	54.2	13.0	143.					
F. Chandler	3	552.								96.	185.			
	10		486.											
8. Scottsdale	8		221.							79.	174.	88.	111.	22.
Helicopter 1300 hrs	30	123.6												
	150	111.6												
	305	101.9												
Central														
1. Central Phoenix	10		112.									50.	45.	17.
2. South Phoenix	10		206.							91.	119.	103.	82.	21.

*Aerodynamic diameter size fractions

**Geometric diameter size fractions

( )Numbers in parentheses are microscopical estimates of mass

TABLE 6. MASS FLUX FOR 17 NOVEMBER, 1975

Height, m	Conc. $\mu g/m^3$	Wind, m/sec	Mass Flux, $mg/sec\text{-}m^2$
Upwind			
0-6	199.	1.0	.20
6-20	175.	1.0	.18
20-50	75.	1.1	.09
50-200	100.	1.2	.12
200-500	105.	1.8	.19
Downwind			
0-6	318.	1.0	.32
6-20	320.	1.0	.32
20-50	134.	1.1	.15
50-200	112.	1.2	.13
200-500	102.	1.8	.18
Central			
10	176.		

in mass flux in the layer 200-500 m, but at lower heights the mass flux is greater leaving the city than entering it.

MICROSCOPIC PARTICLE CHARACTERIZATIONS

Upwind Helicopter Samples

Upwind (Track 1) samples contained primarily large, angular mineral particles, typical of the area west of Phoenix. Clays, humus, and minerals less than 5 μm were also present but did not constitute the bulk of the sample mass. Trace to minor concentrations or rubber tire dust [illegible] fine carbonaceous particles (typical of tailpipe emissions) were p[illegible]. In addition, recrystallized (ammonium) sulfate needles were present in minor to major concentrations.

Particle sizes and type concentrations varied with altitude. As expected, rubber tire particles decreased in numbers with increasing altitude, while the smaller clay particles and fine carbonaceous material increased. At 30 m, the bulk of the sample mass rested in 15-25 μm particles while at 150 m and 305 m, the bulk of the mass was in the 5-10 μm particles.

Downwind Helicopter Samples

Downwind (Track 11) samples also contained primarily mineral particles. As with most of the ground sites east of Phoenix, the helicopter sampler showed lower concentrations of calcite and biotite mica and higher concentrations of iron oxides and iron-rich clays compared to samples taken west of Phoenix. In addition to the mineral differences, downwind samples showed higher concentrations of rubber tire particles, fine carbonaceous material (tailpipe emissions), and recrystallized sulfate needles. Total mass loadings were only slightly higher at the downwind sites. Particle sizes tended to be small. At 30 m, the bulk of the sample mass rested in the 5-15 μm particles; at 150 m and 305 m, the sample mass shifted to the 5-10 μm particles.

Particle size was the major difference between upwind and downwind samples. The downwind particles tended to be smaller and did not follow the upwind trend of decreasing particle size with increasing altitude.

Upwind (West) Hi-Vol Filter Samples

Site A. American Graduate School, 216 $\mu g/m^3$

The sample consisted primarily of large mineral particles (quartz, feldspars, mica, calcite), many of which were coated with clays and clay aggregates. Humus clumps (black soil) constituted a trace to minor constituent. Biological materials -- mostly trichomes and spores -- also represented a very trace component. Automobile emissions, including rubber tire dust, were present as a minor sample component.

Particle size on a number basis was small -- 4 μm. On a mass basis, however, approximately 40% of the sample mass was greater than 15 μm, and 50% in the 5-15 μm range.

The majority of the mineral particles were not sharp, angular, and clean-surfaced. While clean, angular quartz particles were present, they represented only a small portion of the mineral particles present. Rather, the minerals tended to have rounded edges and irregular surfaces. Most of the large minerals had clays adhering in clumps to the surface.

Site B. Parker Residence, 214 $\mu g/m^3$

The sample consisted primarily of large mineral particles (quartz, feldspars, mica, calcite), some of which were coated with clays. Clay aggregates and humus together represented a major portion of the sample. Pollens, spores, trichomes, and a few cotton fibers were present in very trace concentrations. Rubber tire dust and tailpipe emissions were present in minor to major concentrations.

Modal particle size was approximately 4 μm. Approximately 50% of the sample mass was in the greater than 15 μm particles and 40% in the 5-15 μm particles.

Parker showed a stronger automobile influence than American Graduate School -- more and larger rubber tire particles, a higher percentage of clean, sharp, angular quartz particles, and fewer clay aggregates.

Site 5. West Phoenix, 239 $\mu g/m^3$

The large minerals were again the primary sample components, with clay and humus aggregates contributing a major portion of the sample mass. The biological particles were present in trace concentrations. Rubber tire dust and tailpipe emissions together were a minor to major component. In addition, some type of incinerator was operating nearby, as evidenced by charred paper fragments, iron oxide aggregates, and partially fused glassy fly ash material. The incinerator contribution to the mass loading was very small.

Modal particle size was larger than both of the other west sites for this date -- ∿5 μm. The higher mass loading at West Phoenix can be attributed to a higher number (and therefore mass) percent of the larger diameter particles. Approximately 55% of the sample mass was in the greater than 15 μm particles.

Compared to the two other west sites sampled on the 17th, West Phoenix showed a much stronger automobile influence. Many of the minerals and rubber tire particles appear to have been re-entrained several times, as evidenced by the gouged surfaces of the tire particles and the rough surface texture of the minerals.

Downwind (East) Hi-Vol Filter Samples

Site D. Indian Reservation, 407 $\mu g/m^3$

The sample was primarily minerals (quartz, feldspars) and clay aggregates. The clays coating other mineral particles and the clay aggregates were quite red in color, indicating a high iron content. Biological particles were mostly trichomes and moth scales. A few large pieces of shredded plant tissue and cotton fibers were present. These biological particles, together with the few small fertilizer particles seen, constituted a trace component of the sample. Tailpipe emissions and rubber tire particles were a minor sample component.

Particle size was fairly large. Approximately 45% of the sample mass was in the greater than 15 μm particles with 45% in the 5-15 μm range.

Overall, the majority of the mineral particles showed rounded edges with irregular, clay-coated surfaces. Very few clean, sharp, angular quartz particles were present. The amount of rubber tire dust (especially the large fragments) seemed high for the few numbers of sharp, angular, quartz particles.

Compared to the west sites, the Indian Reservation showed higher concentrations of clay aggregates. The iron content of these clays also appeared high. The mineral fragments were more heavily coated with clays. Mica concentrations were lower. Rubber tire particles were considerably larger than any seen at the west sites.

Site 8. Scottsdale, 221 μg/m^3

The sample consisted primarily of large mineral particles -- quartz, feldspars, micas. Clay aggregates were a major component. Together, trichomes, shredded plant tissue, and cotton fibers represented a very trace component. Automobile emissions were a major sample component. Rubber tire particles were quite large and numerous; however, the amount of the fine, black tailpipe emissions seen was relatively small compared to the rubber tire concentration. All types of particles were very large. Approximately 55% by mass were greater than 15 μm with 40% in the 5-15 μm range.

Compared to the Indian Reservation, the clay concentration was much lower while the rubber tire concentration was higher. A higher percentage of the quartz particles were clean and angular. Clay coatings were less frequent and less thick on the Scottsdale minerals. These findings suggest that there are fewer unpaved roads for autos to travel over in the Scottsdale area compared to the Indian Reservation.

Compared to the west sites, Scottsdale showed the higher iron content clays and minerals as did the Indian Reservation. Total clay concentrations were lower at Scottsdale than they were at Parker and American Graduate School, while rubber tire concentration was higher.

Site 9. Mesa, 157 μg/m^3

The sample consisted primarily of large mineral particles -- quartz, calcite, feldspars, mica. Clay was only a minor sample component. Very few biological particles, representing a very trace component, were present. Rubber tire dust was a major sample component; tailpipe emissions were low however, compared to the numbers and size of the rubber tire dust.

Particle size was large: approximately 60% of the particles by mass were greater than 15 μm.

The Mesa sample was more similar in composition to Scottsdale than the Indian Reservation. Clay concentrations were lower, rubber tire dust concentrations were higher, and the percentage of clean, angular quartz, calcite, and other mineral particles vs. the clay-coated, rounded ones was higher than at the Indian Reservation. Iron concentration should be even lower at Mesa compared to Scottsdale, due to fewer clay aggregates.

Site F. Chandler, 552 $\mu g/m^3$

The sample was primarily minerals and clay. Biological particles, though present in larger numbers and larger sizes than at any other site, still represented only a trace sample component. Trichomes were the main type of biological particle present with plant tissue, spores and pollens, and cotton fibers in decreasing order of abundance. No fertilizer particles were noted. Iron oxides, including magnetite species, were present in minor concentrations; particle morphology indicated that soil was their primary source. Automobile emissions were a very minor component of the sample. A local incinerator was also contributing trace quantities of burnt paper fibers, carbonaceous flakes, soot balls, and glassy fly ash aggregates to the sample.

Particle size and type of this Chandler sample were more similar to the Indian Reservation than to any of the other west sites. Clay concentrations were high, and the majority of the mineral particles were irregular-surfaced, round-edged with clay coatings, again suggesting more bare, undeveloped ground present compared to Scottsdale.

Site 16. Chandler, 485 $\mu g/m^3$

Quartz, feldspars, mica, and calcite were the primary components of this sample. Clay was a major sample component. Biological particles were present in trace concentrations. Iron oxides represented a minor portion of the sample. Automobile emissions were a minor to major sample component.

Compared to the tower Chandler site (F), the automobile emissions were higher. Higher percentages of quartz, clean, angular mineral particles, and lower percentages of clay aggregates were the major differences between the two Chandler sites. While Site 16 contained approximately 30% fewer particles than the F site, the larger particle sizes at 16 kept the mass loading high.

Central Hi-vol Filter Samples

Site 1. Central Phoenix, 112 μg/m^3

The sample contained primarily quartz, feldspars, and mica particles. Clay was a minor to major component. Very few biological particles (mostly trichomes) were present. Automobile emissions were a minor to major component. Unlike most central city sites, the Central Phoenix site was not heavily loaded with fine carbonaceous material indicative of heavy automobile traffic.

Many of the quartz particles were sharp, clean, and angular. Most of the other minerals, however, had more rounded edges but highly broken, roughened surfaces. Some of the minerals were seen to have carbonaceous material and clays embedded in surface gouges, suggesting re-entrainment.

Particle size was smaller than at most of the other sites. Approximately 45% of the particles by mass were greater than 15 μm with 15% less than 5 μm.

The mineral and clay types were more similar to the west sites than the east sites. Large flakes of mica, seen in abundance at the west sites and less frequently at the east sites, were present in abundance at Central Phoenix. The clay aggregates present were identical to those seen at the west sites. Possibly some transport of materials indigenous to the western Phoenix soil was occurring.

Site 2. South Phoenix, 206 μg/m^3

The sample was primarily quartz and feldspars. Mica and calcite were each major components. Clay aggregates were a minor to major sample component. Trichomes and paper fibers together represented a trace concentration of biological materials in the sample. Automobile emissions were present in major concentrations.

Particle size was the smallest at this site compared to the other sampling sites. Approximately 40% of the particles by mass were greater than 15 μm while 20% were less than 5 μm.

As with Central Phoenix, a high percentage of the mineral particles showed sharp, angular edges, and extremely mangled surfaces. Particle size was smaller than at Central Phoenix. More clay aggregates were present. While the mineral composition was more similar to the west sites vs. the east sites (as was the case for Central Phoenix), fewer and smaller mica particles were present.

ELEMENTAL ANALYSES

Tables 7 and 8 present elemental concentrations, as determined by x-ray fluorescence, for the dichotomous samples and Andersen final filters, respectively. It should be emphasized that the Andersen final filters contain only those particles smaller than 0.8 μm.

TABLE 7. X-RAY FLUORESCENCE ANALYSES OF DICHOTOMOUS SAMPLES FOR 17 NOVEMBER, 1975
Mass Percent

Sampling Sites	Stages*	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb	Sum
Upwind																											
A. Am. Grad. School 3 m																											
B. Parker 3 m																											
5. West Phoenix	F		2.3		3.9		0.4	0.7					0.8				.06	.14		.56						1.7	10.
6 m	C	2.6	10.9		0.4		1.1	3.0	0.3			.05	3.7			.14	.15	.05		.09		.03				0.22	23.
Downwind																											
D. Indian Res. 3 m																											
E. Mesa	F	0.6	2.7		6.3		0.5	1.1					1.0			.09	.21	.26		.90						2.8	16.
3 m	C	1.6	7.1		0.4		0.9	3.0	0.2				2.0			.04	.05	.04		.08		.02				0.2	16.
F. Chandler	F	1.2	5.3		2.4		0.9	1.2					1.5			.11	.17	.11		.16						0.46	14.
3 m	C	3.0	12.0		0.4	0.1	1.7	3.0	0.3			.06	3.7	.02		.04	.07	.02		.03	.01	.03					24.
8. Scottsdale	F		2.4		6.5		0.5	0.8					0.6			.07	.13	.35		.8						2.6	15.
3 m	C		9.7		0.5	0.1	1.3	3.8	0.2			.05	3.0	.02		.15	.19	.05		.1		.03				0.3	22.
Central																											
1. Central Phoenix 10 m																											
2. South Phoenix	F	0.5	2.7		3.6		0.5	1.0					0.8				.12	.16		.39						1.3	11.
10 m	C	2.6	12.4		0.5		1.5	4.7	0.3			.04	3.6			.03	.09	.04		.07		.04				0.05	26.

*F=Fine Filter (<3.5 μm particles)
C=Coarse Filter (>3.5 μm particles)

TABLE 8. X-RAY FLUORESCENCE ANALYSES OF ANDERSEN FINAL FILTERS FOR 17 NOVEMBER, 1975
(Concentration, $\mu g/m^3$)

Site	Height m	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb
Grad School																										
	3				2.5											.06	.06	.03		.18						.80
	10				1.6								.11			.07	.04			.09						.50
	30				1.9											.08		.03		.08						
Parker																										
	30				1.2								.18			.06	.044			.12						.66
Mesa																										
	3				2.5								.08			.05	.12	.08		.35						1.2
	10				2.5								.28			.08	.10	.08		.28						1.0
	30				2.7								.10			.10	.10	.03		.11						.67

SECTION 7

SECOND SAMPLING PERIOD - TUESDAY, 18 NOV. 1975, 11:00 A.M. to 6:00 P.M.

MASS FLUX DETERMINATIONS

A storm center was passing by with winds from the west. At 1100 hrs, the surface wind was light from the southwest. At 1130 hrs, the wind increased suddenly to 3 m/sec from the west (230°) at the County Building, 9 m/sec at Goodyear, and 11 m/sec at Glendale. This synoptic wind was in the same direction as the expected drainage wind, and in any case was strong enough to obscure any normal drainage wind.

Tables 9 and 10 show average wind profiles for the afternoon. Figure 6 shows that there was a normal lapse rate for these wind conditions.

Helicopter data presented in Table 11 show considerable variation between runs. Nephelometer data show peaks indicating local dust sources for the 30 m run. Downwind nephelometer concentrations are the same as upwind, suggesting that with these wind conditions the city was not the major source of fines.

Table 12 summarizes the mass concentrations from all types of samplers. Table 13 presents calculated mass flux for each height increment. The mass flux up to 50 m is greater downwind than upwind. Above 50 m there is no difference in flux upwind and downwind of the city.

MICROSCOPIC PARTICLE CHARACTERIZATIONS

Upwind Helicopter Samples

The Track 1 upwind samples varied in composition at the various altitudes and sampling times. In all samples, minerals typical of the west Phoenix area were the primary component. Trace to minor concentrations of rubber tire dust and tailpipe emissions together constituted a minor sample component. These components did tend to decrease with increasing sampling altitude, and

TABLE 9. AVERAGE WIND PROFILE FOR 18 NOVEMBER, 1975
1100 to 1700 Hrs

Vector Average			Arithmetic Average
Height m	Speed m/sec	Direction Degrees	Speed m/sec
50	6.4	247.6	6.9
100	7.9	247.4	8.5
150	7.5	246.0	8.0
200	7.3	245.9	7.8
250	7.6	246.5	8.1
300	7.8	246.5	8.4
350	7.9	246.2	8.4
400	7.9	245.4	8.4
450	7.9	244.4	8.4
500	7.9	244.6	8.4
550	7.9	244.9	8.3
600	7.8	244.4	8.2
650	7.7	243.5	8.0
700	7.7	242.9	8.1
750	7.9	242.4	8.3
800	8.0	242.0	8.4
850	8.1	241.7	8.5
900	8.7	240.5	9.1
950	9.1	239.0	9.6
1000	9.1	236.9	9.5
1050	9.1	235.5	9.5
1100	9.0	235.7	9.4
1150	9.0	234.9	9.4
1200	9.0	233.2	9.5
1250	9.0	231.6	9.5
1300	9.0	230.0	9.5
1350	9.1	228.9	9.7
1400	9.3	227.9	9.8
1450	9.3	226.8	9.9
1500	9.4	225.7	9.9
1550	9.4	224.3	10.0
1600	9.6	223.7	10.1
1650	9.8	223.8	10.4
1700	9.9	223.1	10.5
1750	10.0	222.1	10.5
1800	10.2	220.8	10.8
1850	10.4	219.7	11.0
1900	10.6	219.3	11.1
1950	8.7	223.5	9.4
2000	8.7	224.3	9.3

TABLE 10. WIND PROFILES AT PILOT BALLOON SITES FOR 18 NOVEMBER, 1975
Vector Averages

Height m	Central Speed m/sec	Central Dir. Degrees	Mesa Speed m/sec	Mesa Dir. Degrees	Goodyear Speed m/sec	Goodyear Dir. Degrees	Grad School Speed m/sec	Grad School Dir. Degrees
Surface					6.	244.		
50	5.7	266.0	6.6	268.3	8.1	238.1	6.4	225.9
100	7.5	264.3	8.2	268.1	8.9	236.6	8.2	226.6
150	7.2	262.0	7.1	267.6	9.2	235.2	7.5	227.7
200	6.9	260.7	6.9	266.6	9.2	234.4	7.2	228.6
250	7.0	260.2	7.6	269.5	9.1	234.4	7.7	229.2
300	7.3	258.9	8.0	269.5	9.2	234.4	7.9	229.8
350	7.5	256.9	8.0	269.1	9.3	234.9	7.8	230.4
400	7.7	254.3	7.9	268.0	9.2	235.0	7.7	230.1
450	8.0	251.6	7.8	266.6	8.4	235.2	7.7	229.4
500	8.2	249.9	8.0	264.4	8.6	235.5	7.5	230.3
550	8.3	248.9	8.5	261.9	8.2	236.8	7.1	231.5
600	8.1	248.0	8.6	259.6	7.9	236.7	7.0	232.2
650	7.9	247.3	8.5	257.2	7.8	236.0	6.9	232.6
700	7.8	246.9	8.9	255.7	7.9	235.4	6.4	232.2
750	7.7	246.6	9.5	254.6	8.0	234.4	6.5	231.4
800	7.8	245.4	9.7	254.3	8.2	234.4	6.8	231.2
850	7.9	244.0	9.7	254.1	8.3	235.2	6.7	231.6
900	8.1	242.9	10.9	250.6	9.0	234.4	7.3	232.3
950	7.9	238.2	11.7	249.1	9.6	234.4	7.7	233.3
1000	7.8	235.8	11.7	247.1	9.8	231.9	7.5	232.0
1050	7.6	233.4	11.7	245.2	9.7	230.9	7.3	231.2
1100	8.2	231.3	11.7	243.4	9.1	234.3	7.3	231.6
1150	8.8	229.7	11.7	242.1	8.5	234.5	7.4	231.2
1200	9.5	228.3	11.6	241.2	8.1	231.7	7.4	230.0
1250	10.6	227.0	11.2	239.6	8.0	230.5	7.5	228.3
1300	10.5	225.7	10.3	237.6	8.0	230.2	7.6	228.4
1350	10.6	224.3	10.7	235.4	8.1	229.2	7.8	228.5
1400	10.7	223.0	11.1	233.5	8.2	226.3	7.7	228.7
1450	11.2	221.5	10.5	232.6	8.2	226.1	7.9	225.7
1500	11.5	220.1	10.2	231.4	8.2	227.6	8.1	224.6
1550	11.6	218.5	10.1	229.5	8.3	226.4	8.3	224.2
1600	11.9	217.6	10.2	228.7	8.3	226.0	8.4	223.7
1650	12.2	217.7	10.6	229.2	8.5	226.3	8.5	223.5
1700	12.6	216.8	10.6	226.6	8.5	225.3	8.7	223.7
1750	12.9	215.5	10.5	227.5	8.3	223.8	8.9	224.0
1800	13.4	214.7	10.5	224.4	8.4	222.8	9.1	223.8
1850	14.0	214.0	10.5	221.4	8.5	222.2	9.2	223.5
1900	14.3	212.6	10.9	220.8	8.6	222.8	9.1	223.9
1950	.0	.0	.0	.0	8.7	223.5	.0	.0
2000	.0	.0	.0	.0	8.7	224.3	.0	.0

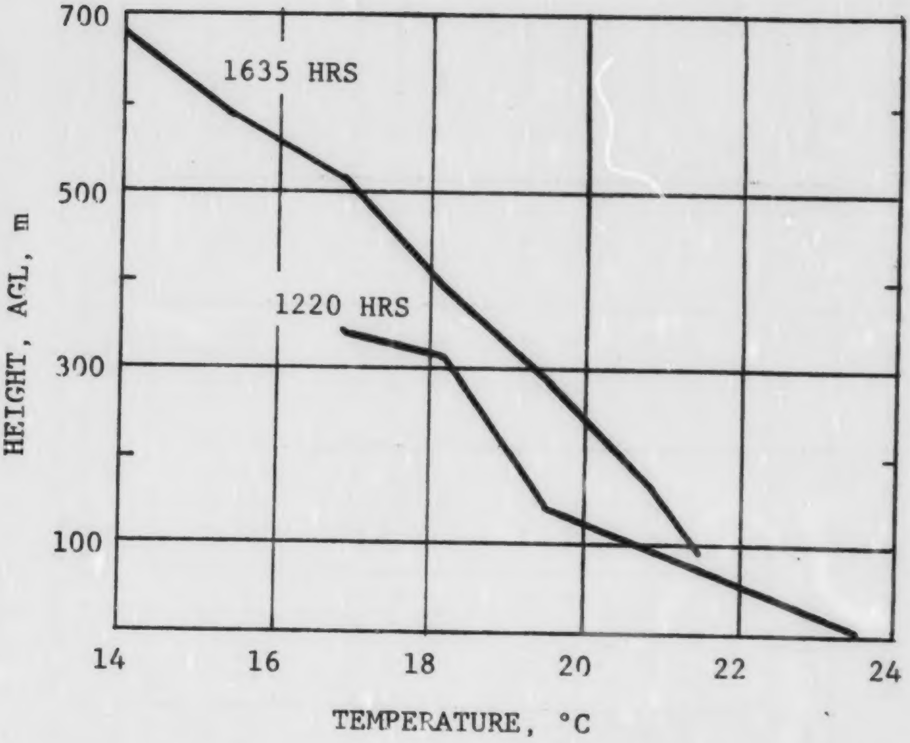

Figure 6. Height vs. Temperature, 18 November, 1975.

TABLE 11. HELICOPTER SAMPLING DATA FOR 18 NOVEMBER, 1975

Track	Time, min Start	Δ	Altitude ft	m	Filter No.	Wt, μg	Flow, m^3	Conc, $\mu g/m^3$	Nephelometer, Volts** (Position in Track) N	Midpoint	S	Average
West-Upwind												
1	1226	12	800	244	117541	506	13.70	36.9	1.9	1.9	1.8	1.9
1	1252	19	100	30	117542	1442	11.83	121.9	1.9	2.0	1.9	1.9
1	1540	13	500	150	117524	(800)	8.09	(99.)	1.5	1.6	1.5	1.5
1	1556	17	300	90	117540	(450)	10.58	(43.)	1.5	1.6	1.6	1.6
1	1615	15	100	30	117535	433	9.34	46.4	1.6	1.7	1.5	1.6
Southwest												
3	1315	7	800	244	117537	359	4.36	82.3	2.0	2.0	1.8	1.9
3	1324	7	500	150	117538	(150)	4.36	(34.)	2.0		1.8	1.9
3	1332	6	100	30	117544	(275)	3.74	(74.)	2.0		1.7	1.9
East-Downwind												
11	1647	20	500	150	117530	657	12.45	52.8	1.6	1.6	1.5	1.6
11	1709	18	100	30	117517	(575)	11.21	(51.)	1.6	1.5	1.5	1.5

**The nephelometer responds to μm-sized particles, not to the full range of sizes collected by the samplers. The table shows the shape of the nephelometer trace and the average readings at ends and midpoint of each helicopter run.

( )Numbers in parentheses represent microscopical estimates of mass

TABLE 12. MASS CONCENTRATIONS FOR 18 NOVEMBER, 1975

	Height	Mass Concentrations, μg/m^3												
		Hi-vol		Andersen*						Dichotomous*		Hi-vol (Microscope Est.**)		
	m	Tower	County	>25 μm	>15 μm	>8 μm	>2.5 μm	>0.9 μm	Sum	Fine <3.5 μm	Coarse >3.5 μm	>15 μm	5-15 μm	<5 μm
Upwind														
A. Am. Grad. School	3	211.			104.5	28.8	27.7	1.6	163.			127.	74.	10.
	10				61.8	23.5	14.1	--	99.					
	30			29.2	--	36.9	--	13.3	79.					
B. Parker	3	164.4		44.3	--	20.1	22.1	9.5	96.					
	10			5.3	--	8.6	11.2	9.7	35.					
	30				40.1	14.1	23.9	--	78.					
C. Page	3				32.2	16.5	17.9	43.1	110.					
	10			36.2	--	13.3	--	2.7	52.					
	30				60.5	10.2	--	11.0	82.					
5. West Phoenix	6		384.							33.	87.			
Helicopter 1300 hrs	30	121.9												
	244	36.9												
	30	(74.)												
	150	(34.)												
	244	82.3												
Helicopter 1600 hrs	30	46.4												
	90	(43.)												
	150	(99.)												
Downwind														
D. Indian Res.	3				33.3	13.0	12.7	--	59.					
	10				43.2	15.4	18.0	8.5	84.					
	30			42.4	93.1	60.	20.	--	216.					
E. Mesa	3		209.		77.1	17.3	36.3		131.	63.	176.			
	10				156.7	51.3	61.1		269.					
	30			34.6		10.7	24.4	--	70.					
F. Chandler	3	474.												
	10		439.							33.	132.			
	30													
8. Scottsdale	8		441.							290.	170.	309.	110.	22.
Helicopter	30	(51.)												
	150	52.8												
Central														
1. Central Phoenix	10		287.							37.	99.	140.	130.	14.
2. South Phoenix	10		257.							30.	469.	154.	90.	13.

*Aerodynamic diameter size fractions
**Geometric diameter size fractions

( )Numbers in parentheses are microscopical estimates of mass

TABLE 13. MASS FLUX FOR 18 NOVEMBER, 1975

Height, m	Conc. µg/m³	Wind, m/sec	Mass Flux, mg/sec-m²
Upwind			
0-6	186.	5.	.93
6-20	138.	5.	.69
20-50	80.	6.	.48
50-200	59.	7.	.41
200-500	60.	7.9	.47
Downwind			
0-6	222.	5.	1.11
6-20	310.	5.	1.55
20-50	112.	6.	.67
50-200	53.	7.	.37
200-500	-	7.9	-
Central			
10	294.		

as the day progressed. Clay, humus, and recrystallized sulfate needle concentrations appeared to vary the most. These materials generally tended to increase at the lower sampling altitudes as the day progressed.

Particle size did not show the typical trend of decreasing particle size with increasing altitudes. The early afternoon samples showed similar particle sizes at 30 m and 244 m; sample mass was mainly in the 15-25 μm particles. The late afternoon samples showed significantly larger particles with increasing altitude. At 30 m, the bulk of the sample mass was in the 10-15 μm particles while at 150 m, the 15-25 μm particles predominated.

The Track 3 upwind samples showed slightly different particle types and significantly smaller particles from the Track 1 upwind samples. Particle types and size did not vary significantly in this group with increasing altitude. Sulfate crystals and combusted fragments were higher in concentration in all the Track 3 samples compared to the Track 1 samples. Sample mass tended to concentrate in the 5-15 μm particles at all altitudes.

Downwind Helicopter Samples

Both Track 11 samples contained primarily large mineral particles, with smaller amounts of clays and humus. Rubber tire dust, tailpipe emissions, combustion fragments and fly ash particles together constituted a minor portion of the sample; however, all these materials were present at higher concentrations than the late afternoon Track 1 samples at the same altitudes.

Particle size did not tend to decrease with increasing altitude; at both 30 and 150 m, the bulk of the sample mass was in the 20-25 μm particles. The downwind samples also showed larger particle sizes than the late afternoon upwind samples.

Upwind (West) Hi-Vol Filter Samples

Site A. American Graduate School, 211 $\mu g/m^3$

The sample was primarily large mineral particles (quartz, feldspars, mica, and calcite). Clay aggregates were a major sample component. Pollens, spores, and trichomes together were a trace sample component. Automobile emissions (mostly rubber tire particles) were a minor sample component.

Particle size was quite large. Approximately 60% of the particles were greater than 15 μm, while 35% were in the 5-15 μm range.

The major differences between this sample and the one collected on the 17th were related to particle size. The fine, discrete clay particles and fine carbonaceous material seen on the 17th were practically absent on the 18th. Overall, the particle sizes were much larger than on the 17th. More biological material was also seen.

Site B. Parker, 164 μg/m^3

Quartz, feldspars, mica, and calcite were the primary sample components. Clay aggregates were a major sample component. The biological particles -- pollen, spores, and trichomes -- were a minor sample component. Automobile emissions were present in minor concentrations.

The particle size was large; approximately 55% of the particles by mass were greater than 15 μm with 40% in the 5-15 μm range.

As with the American Graduate School site, the particle size increased significantly from the 17th to the 18th. Most of the fine clays and carbonaceous materials seen on the 17th were absent on the 18th. Biological particles were larger and more numerous.

Site 5. West Phoenix, 384 μg/m^3

The sample was primarily minerals and clay aggregates. Biological materials accounted for less than 0.1% of the sample mass. Automobile emissions (mostly rubber tire dust) were minor to major sample components.

The higher mass in this sample compared to the previous day was due mainly to higher loadings of the larger particles. By mass, approximately 70% of the particles were greater than 15 μm. Less than 10% of the sample mass was accounted for by particles below 5 μm.

The mineral particles in general were cleaner and smoother on the surface compared to the 17th. Heavily gouged minerals coated with carbonaceous particles were fewer in number. As with the other west sites, concentrations of fine carbonaceous (tailpipe) material and discrete clay particles were significantly lower than on the 17th.

Downwind (East) Hi-Vol Filter Samples

Site 8. Scottsdale, 441 μg/m^3

The sample was primarily large minerals -- quartz, feldspars, mica, and calcite. Clay aggregates were a major component. Biological particles -- trichomes, plant tissues, and cotton fibers -- though greater in number than on the 17th, still represented only a trace sample component. Automobile emissions -- mainly rubber tire dust -- represented a minor to major portion of the sample.

Particle size was large; approximately 70% of the sample by mass was represented by particles greater than 15 μm.

Compared to the 17th, the sample from the 18th showed higher concentrations of mica and calcite and lower concentrations of fine carbonaceous material. The mica and calcite possibly were transported from the western Phoenix area. Although rubber tire particles were larger and more numerous than on the 17th, the increased mineral loadings decreased the tire dust's percentage of the sample mass. The mineral particles were cleaner and more angular than on the 17th.

As with the upwind sites, the fine materials decreased in concentration from the 17th. Particle size increases were more dramatic at the downwind sites compared to the upwind sites.

Site 9. Mesa, 209 μg/m^3

The sample was primarily very large minerals -- quartz, feldspars, calcite, and mica. Clay aggregates were a major component. Biological particles were present in trace concentrations. Rubber tire fragments were large, numerous, and therefore still constituted a major sample component. The fine carbonaceous material (tailpipe) was present in trace levels.

Particle size was extremely large. Approximately 80% of the sample mass was contained in particles greater than 15 μm. In fact, at least half of that mass was represented by particles greater than 40 μm. Less than 20% of the mass was accounted for by particles less than 5 μm.

The sample was significantly different from the one collected on the 17th. While the 18th sample contained less than 30% of the number of particles seen on the 17th sample, it contained 30% more mass. The fine carbonaceous material and discrete clay particles were all but absent on the 18th. Mica and calcite concentrations were higher on the 18th, again suggesting transport of these materials from the west Phoenix area.

Site F. Chandler, 474 $\mu g/m^3$

Minerals and clay aggregates were the primary materials in the sample. Biological particles (mostly trichomes and cotton fibers) were present in very large sizes, but were not numerous enough to constitute more than a trace component. A local incinerator contributed trace quantities of carbonaceous flakes and glassy fly ash material. Automobiles contributed only minor quantities of particles to the sample.

By mass, approximately 65% of the particles were greater than 15 μm with only 10% of the sample mass in particles less than 5 μm.

As with the other downwind sites, the differences between the 17th and 18th samples were much more dramatic at the downwind (east) than the upwind (west) sites. At the F Chandler site, in addition to the increase in particle size (mostly due to the decrease in numbers of fine carbonaceous material and discrete clay particles), the clay aggregate concentrations decreased. The mineral particles tended to be more sharp and angular than on the 17th.

Site 16. Chandler, 439 $\mu g/m^3$

This sample was primarily minerals -- quartz, feldspars, calcite, and mica. Clay aggregates were present at minor to major concentrations. Biological particles were a trace component. Automobile emissions (mostly rubber tire dust) represented a minor sample portion.

By mass, approximately 70% of the particles were greater than 15 μm with only 10% of the sample mass in particles below 5 μm in size.

The Site F and Site 16 Chandler samples were closer in composition to each other on the 18th than they were on the 17th. The Chandler 16 site was the only downwind (west) site which did not show drastic changes from the 17th. Fine carbonaceous material and clays were present at very low concentrations on the 17th and therefore could not decrease drastically on the 18th.

Central Hi-Vol Filter Samples

Site 1. Central Phoenix, 287 $\mu g/m^3$

The sample was primarily large mineral particles -- quartz, feldspars, and mica. Clay aggregates were present as a major component. Biological particles (trichomes and cotton fibers), though larger and more numerous than on the 17th, still constituted only a trace sample component. Automobile emissions (mostly rubber tire dust) were present as a minor sample component.

Particle sizes were larger than on the 17th. By mass, approximately 60% of the particles were greater than 15 μm and only 5% were less than 5 μm.

Besides the difference in particle size from the 17th, the sample showed lower clay aggregate and rubber tire particle concentrations. As with all other samples of the 18th, the concentrations of fine clay particles and fine carbonaceous materials were tremendously lower on a number basis compared to the 17th. This decrease in carbonaceous particle concentration did not represent a decrease in traffic, as the numbers of rubber tire particles and freshly cleaved quartz particles were similar to the 17th. As with the upwind sites, sample differences between the 17th and 18th were not as great as those for the downwind sites.

Site 2. South Phoenix, 257 $\mu g/m^3$

The sample consisted primarily of large mineral particles and clay aggregates. Biological particles, though larger and more numerous than on the 17th, were only a trace component. Automobile emissions contributed only a minor portion of the sample mass.

Particles were quite large. By mass, 65% of the particles were greater than 15 μm with less than 5% below 5 μm in size.

Compared to the 17th, more mica and quartz particles were present. Unlike the 17th, the quartz was the only mineral type to appear as clean, freshly broken material; most of the other minerals were damaged (some apparently by chemical attack) and had many other fine particles attached.

The sample did show the decreased fine carbonaceous and clay particle concentrations. However, unlike Central Phoenix, the South Phoenix site showed the same drastic sample change from the 17th to the 18th as the east sites showed.

ELEMENTAL ANALYSES

Tables 14 and 15 present elemental concentrations, as determined by x-ray fluorescence, for the dichotomous samples and Andersen final filters, respectively.

TABLE 14. X-RAY FLUORESCENCE ANALYSES OF DICHOTOMOUS SAMPLES FOR 18 NOVEMBER, 1975

Mass Percent

Sampling Sites	Stages*	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb	Sum
Upwind																											
A. Am. Grad. School 3 m																											
B. Parker 3 m																											
C. Page 3 m																											
5. West Phoenix	F	1.6	4.1		4.0		0.7		1.3				1.4					0.9		.62						1.4	15.
6 m	C	3.5	14.2		0.5		1.6	4.6	0.4			.06	1.8	0.4			0.4	0.1		.07		.05				.04	
Downwind																											
D. Indian Reservation 3 m																											
E. Mesa	F				1.2															.24							1.
3 m	C	1.7	10.9		.6		1.4	5.3					3.4				.09			.06							23.
F. Chandler 3 m																											
10 m	F	1.8	7.9		2.4		1.4	2.6					2.0					.04		.15							18
	C	2.9	11.9		0.5	.15	1.6	4.4	0.3			.05	3.5	.02			.02			.02		.03					25
G. Scottsdale	F	.15	.57		0.4		.08	.21					.15					.01		.09						.24	2.
8m	C	1.8	9.4		0.4		1.1	4.7	0.3			.04	2.8	.02			.04	.01		.06		.03				.12	21
Central																											
1. Central Phoenix	F	1.0	4.0		3.3		0.5	1.4					1.1					.07		.34						.78	13.
10 m	C	3.0	12.1		0.5	.07	1.5	5.7	0.3			.04	3.6				.03	.01		.04		.04					27.
2. South Phoenix	F	1.4	5.8		4.0		0.9		2.6				1.5							.20							16.
10 m	C	.6	2.8		0.1		0.4	1.5	.06				.8	.01						.005		.01					6.

*F=Fine Filter (<3.5 μm particles)
C=Coarse Filter (>3.5 μm particles)

TABLE 15. X-RAY FLUORESCENCE ANALYSES OF ANDERSEN FINAL FILTERS FOR 18 NOVEMBER, 1975
(Concentration, $\mu g/m^3$)

Site	Height m	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb
Grad School	3				.73		.11	.24					.43													.14
	10				.56															.02						.14
	30				.52															.014						.11
Parker	3				.4															.03						.16
	10				.3												.02			.01						.09
	30				.3								.06			.05	.03			.02						.11
Page	3				.5								.10							.01						.13
	10				.5															.015						.13
	30				.6															.015						.09
Indian Res.	3				.23								.08			.03	.02			.05						.25
	10				.20								.09							.04						.23
	30				.35								.39			.07	.05			.05						.34
Mesa	3				.14								.09			.03	.05			.06						.24
	10												.11			.04	.05			.05						.20
	30																.03			.03						.14

SECTION 8

THIRD SAMPLING PERIOD - FRIDAY, 21 NOV. 1975, 6:00 A.M. TO NOON

MASS FLUX DETERMINATIONS

The normal morning drainage wind was from an easterly direction. Average profiles are shown in Tables 16 and 17. At Goodyear, the surface wind averaged 1 m/sec at 90° (E).

The temperature profile, Figure 7, showed a strong inversion to 80 m. A weaker inversion extended to 280 m at 0715 hr, and to 430 m at 1100 hr. Light winds of 2 to 4 m/sec were variable easterly from 80 m to about 400 m. A light synoptic wind from 330° (NW) occurred above 700 m and sometimes penetrated to 300 m, with an occasional layer of 30° wind inside this zone. Turnaround of the drainage wind occurred early, 1100 to 1130 hr, because of the drag of this synoptic NW wind. The samplers were set to shut off at noon, however.

Visual observations from South Mountain at 0730 hrs showed a blanket of brown polluted air over the Phoenix area up to the level of South Mountain, 400 m above the valley (2,300 ft MSL).

Visual observation from the County Building at 0900 hrs showed the brown polluted air mass being blown out of city to the west; the east and center side appeared more clear. Carbon monoxide measurements in Table 18 from County telemetry data also showed the same trend, suggesting a correlation with automobile traffic.

The helicopter data in Table 19 show moderate mass concentrations (21 to 45 $\mu g/m^3$) in the early morning, while the nephelometer shows peaks indicating local sources. By noon, the mass concentration had increased to 90 $\mu g/m^3$ upwind, and to 137 downwind at 30 m height. The nephelometer did not increase downwind, however.

TABLE 16. AVERAGE WIND PROFILE FOR 21 NOVEMBER, 1975
0600 to 1030 Hrs

Vector Average			Arithmetic Average
Height m	Speed m/sec	Direction Degrees	Speed m/sec
50	1.8	109.1	2.1
100	2.2	105.4	2.8
150	1.9	98.4	2.7
200	1.9	87.5	2.8
250	2.0	79.4	3.2
300	2.2	70.7	3.3
350	2.3	58.5	3.3
400	2.4	40.8	3.4
450	2.6	22.2	3.4
500	2.7	13.4	3.6
550	2.7	9.5	3.7
600	3.0	6.8	3.8
650	3.1	2.5	3.9
700	3.2	359.5	3.9
750	3.5	353.7	4.2
800	3.8	352.3	4.6
850	3.9	352.1	4.9
900	4.4	353.5	5.4
950	4.8	353.4	5.8
1000	4.8	350.4	5.8
1050	4.7	348.0	5.8
1100	4.7	347.3	5.8
1150	4.7	344.8	5.8
1200	4.6	340.4	5.9
1250	4.7	338.9	5.8
1300	4.6	339.2	5.7
1350	4.7	340.6	5.6
1400	4.8	340.8	5.5
1450	5.1	337.7	5.6
1500	5.3	334.8	5.8
1550	5.6	332.5	5.9
1600	5.8	329.9	6.1
1650	5.9	328.2	6.2
1700	6.1	324.9	6.4
1750	6.2	321.2	6.6
1800	6.1	318.0	6.6
1850	6.0	314.2	6.5
1900	5.7	311.4	6.4
1950	6.1	312.2	6.1
2000	6.0	304.6	6.1

TABLE 17. WIND PROFILES AT PILOT BALLOON SITES FOR 21 NOVEMBER, 1975
Vector Averages

	Central		Mesa		Goodyear		Grad School	
Height m	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees
Surface								
50	2.6	123.1	1.4	111.4	1.9	86.9	1.1	113.3
100	3.6	123.6	1.8	98.5	2.3	74.6	1.4	130.6
150	3.6	123.7	1.6	78.9	2.5	54.5	1.5	164.9
200	3.7	117.4	2.0	68.8	2.8	36.9	1.7	171.9
250	4.1	110.7	2.3	63.2	3.3	24.6	2.1	172.8
300	4.1	105.5	2.8	59.9	3.4	14.2	2.0	157.6
350	3.8	98.8	3.3	56.0	3.5	3.7	1.4	132.7
400	3.1	94.0	3.6	48.0	3.9	354.5	1.5	71.2
450	1.8	92.7	3.6	37.2	4.5	347.9	2.5	38.6
500	1.2	99.0	3.6	30.9	4.8	344.1	3.1	29.1
550	1.1	108.7	3.6	26.1	4.8	341.4	3.4	25.6
600	.6	96.2	3.2	21.3	5.5	345.3	3.7	24.2
650	.4	65.7	2.7	14.5	5.9	344.4	4.0	23.6
700	.9	4.4	2.5	2.8	5.9	346.5	4.2	19.6
750	1.7	343.4	2.3	347.8	6.1	347.7	4.5	14.4
800	2.0	345.8	2.5	338.2	6.1	347.7	5.0	13.2
850	2.2	351.2	2.8	331.9	6.1	347.7	5.5	12.8
900	3.4	358.3	3.1	326.9	6.0	349.2	6.2	12.8
950	4.4	357.5	3.3	322.7	6.0	350.5	6.7	12.7
1000	4.4	347.1	3.4	320.9	5.9	350.4	6.8	12.4
1050	4.3	338.4	3.5	319.3	5.7	350.3	6.9	12.4
1100	4.4	335.3	3.5	318.9	5.5	350.3	7.2	12.8
1150	4.4	330.2	3.7	320.0	5.1	347.7	7.3	11.0
1200	4.3	323.1	4.0	322.6	4.6	341.5	7.2	7.1
1250	4.5	320.0	4.2	328.3	4.4	337.9	7.0	5.0
1300	4.6	320.3	4.3	335.2	4.2	335.8	6.6	3.4
1350	4.7	327.4	4.3	344.0	4.4	332.4	6.2	358.9
1400	4.9	335.4	4.4	347.6	4.7	329.4	5.8	353.1
1450	5.2	333.2	4.9	348.3	5.0	326.9	5.5	345.3
1500	5.4	331.9	5.3	348.1	5.5	324.6	5.4	337.2
1550	5.5	332.6	5.5	346.1	6.2	323.2	5.4	330.1
1600	5.7	331.9	5.7	343.3	6.5	322.1	5.5	323.9
1650	5.8	332.9	5.9	339.8	6.3	321.1	5.7	319.0
1700	5.8	331.9	6.1	337.3	6.6	317.4	6.0	313.5
1750	5.8	329.9	6.2	334.8	7.0	313.2	6.4	308.1
1800	6.0	326.8	6.3	330.2	6.5	309.8	6.2	305.5
1850	6.1	323.6	6.4	324.5	5.9	305.8	5.9	303.1
1900	5.8	320.7	6.6	319.6	5.4	302.8	5.7	301.4
1950	6.1	312.2	.0	.0	.0	.0	.0	.0
2000	6.0	304.6	.0	.0	.0	.0	.0	.0

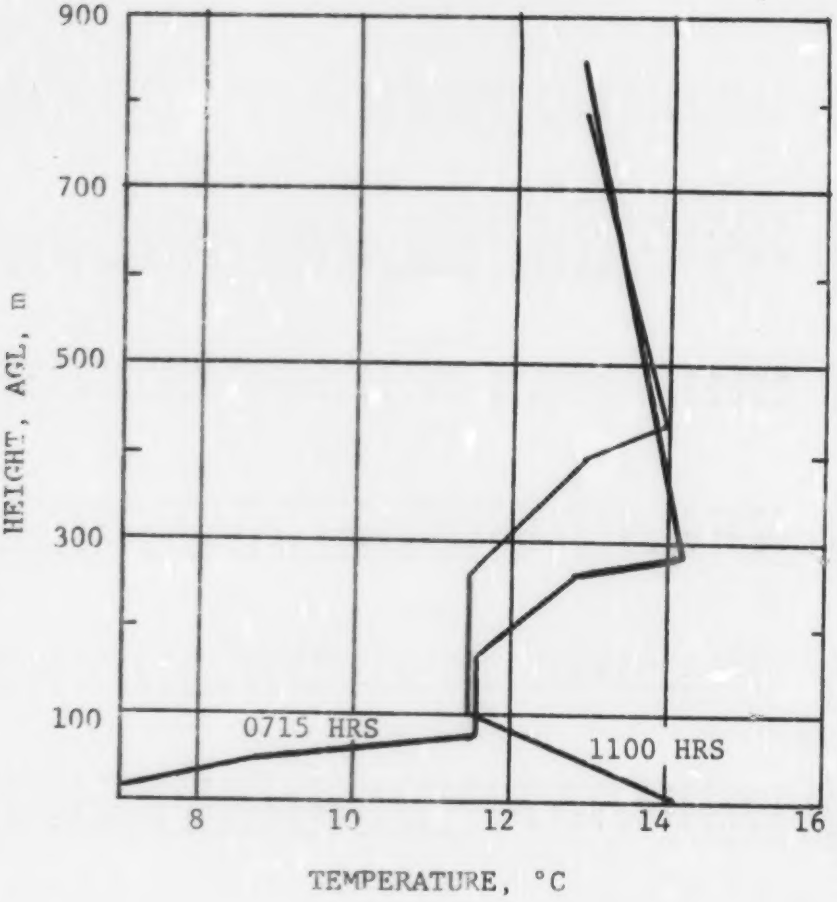

Figure 7. Height vs. Temperature, 21 November, 1975.

TABLE 18. CARBON MONOXIDE CONCENTRATIONS FOR 21 NOVEMBER, 1975

	Station					
Hour	9. Mesa	8. Scottsdale	1. Central	2. South	3. Capitol	4. Glendale
0000	10.3	8.5	22.3	4.4	16.7	2.8
0200	6.2	2.4	6.1	5.1	19.0	1.4
0400	5.7	1.5	7.1	3.9	10.6	0.8
0500	2.7	0.3	4.9	3.3	5.9	0.8
0600	3.1	0.9	3.8	3.1	7.9	0.7
0700	2.4	2.7	4.0	4.2	4.1	1.1
0800	4.1	3.9	6.4	11.3	7.2	2.5
0900	1.8	7.4	7.0	8.3	6.7	8.6
1000	0.6	3.8	4.4	4.6	10.1	8.1

Data Courtesy of Maricopa County Telemetry Network

TABLE 19. HELICOPTER SAMPLING DATA FOR 21 NOVEMBER, 1975

Track	Time, min		Altitude		Filter No.	Wt, μg	Flow, m^3	Conc, $\mu g/m^3$	Nephelometer, Volts** (Position in Track)					Average
	Start	Δ	ft	m					N		Midpoint		S	
East-Upwind														
11	727	19	100	30	117521	~526	11.83	44.5	1.6	∿	1.8	〰	2.7	2.2
11	748	18	500	150	117531	~178	11.21	15.9	1.7	∿	1.5	∿	2.0	1.7
11	810	19	300	90	117529	(250)	11.83	(21.)	1.8	∿	2.3	〰	2.8	2.3
11	834	17	1000	305	117522	(250)	10.58	35.7	1.7	—	1.5	〰	2.3	1.9
11	855	18	2000	610	117523	(75)	11.21	(27.)	1.5	—	1.7	—	1.4	1.5
11	1224	18	500	150	117519	1019	11.21	90.9	1.4	∿	1.4	∿	1.4	1.4
11	1242	19	100	30	117525	1117	11.82	94.4	1.3	∿	1.3	∿	1.5	1.4
West-Downwind														
1	1113	11	100	30	117532	939	6.85	137.1	1.1	∿	1.7	—	1.7	1.5
1	1131	16	500	150	117528	866	9.96	86.9	1.0	—	1.2	∿	1.8	1.3
1	1148	16	1000	305	117526	~580	9.96	58.2	1.0	—	1.3	〰	1.5	1.3

**The nephelometer responds to μm-sized particles, not to the full range of sizes collected by the samplers. The table shows the shape of the nephelometer trace and the average readings at ends and midpoint of each helicopter run.

( )Numbers in parentheses represent microscopical estimates of mass

Table 20 summarizes the mass concentrations. Table 21 presents the mass flux results. In the first 50 m of height, the flux was the same downwind and upwind. For reasons which have not been determined, the high concentrations at Chandler contributed to the high upwind values. The flux was greater downwind from 50 to 350 m.

MICROSCOPIC PARTICLE CHARACTERIZATIONS

Upwind Helicopter Samples

Most of the Track 11 upwind samples contained primarily small mineral particles, typical of the east Phoenix area. Calcite concentrations were high while the clay concentrations were low at the 30 m altitude compared to what is normally seen in this area. Rubber tire particles and tailpipe emissions constituted a minor but significant portion of the 30 to 150 m samples; these materials showed increased concentrations again at 610 m. Recrystallized sulfate needles also constituted a minor (up to major with increasing altitudes) portion of the samples. Observation of recrystallized sulfate, rubber tire, and tailpipe particles suggested that these samples were not truly upwind samples; an urban air mass was being sampled.

Particle size decreased as the altitude increased from 30 m (5-15 μm range) to 150 m (4-8 μm range). At 305 m, slightly larger particles were again seen -- 5-12 μm range. At 610 m, the particle size decreased slightly, placing the bulk of the sample in the 5-10 μm range.

Downwind Helicopter Samples

The Track 1 downwind samples contained primarily large mineral particles and clay aggregates. Rubber tire particles and tailpipe emissions also constituted a minor portion of the samples. Except for lower sulfate concentrations, the downwind samples were not significantly different from the upwind samples, according to particle types.

The particle sizes of the downwind (Track 1) samples were significantly larger than those of the upwind samples. Particle size increased at 150 m (15-25 μm) compared to 30 m (10-20 μm). At 610 m, the particle size decreased again, placing the bulk of the sample mass in the 10-20 μm size range.

TABLE 20. MASS CONCENTRATIONS FOR 21 NOVEMBER, 1975

	Height m	Mass Concentrations, μg/m³												
		Hi-vol		Andersen*						Dichotomous*		Hi-vol (Microscope Est.**)		
		Tower	County	>25 μm	>15 μm	>8 μm	>2.5 μm	>0.9 μm	Sum	Fine <3.5μm	Coarse	>15 μm	5-15 μm	<5 μm
Upwind														
D. Indian Res.	3	187.1			38.3	9.2	44.9	12.7	105.			65.	94.	28.
	10				16.7	9.7	28.3	14.3	69.					
	30				38.6	42.7	--	24.2	106.					
E. Mesa	3	178.	156.		64.5	16.4	36.7	8.7	126.					
	10				3.2	9.8	--	0	13.	41.	123.			
	30			28.4	--	19.0	7.6	0	55.					
F. Chandler	3	433.			148.1	67.1	97.5	2.1	315.					
	10		490.		50.6	38.5	43.6	16.6	149.	75.	157.			
	30			45.4	--	28.6	64.6	15.2	154.					
8. Scottsdale	8		179.									116.	36.	27.
14. Paradise Valley	2		433.											
Helicopter 0800 hrs	30	44.5												
	90	(21.)												
	150	15.9												
	305	35.7												
	610	(27.)												
Helicopter 1230 hrs	30	94.4												
	150	90.9												
Downwind														
A. Am. Grad. School	3	373.										187.	149.	37.
B. Parker	3	182.		39.1	--	29.4	29.3	6.1	104.					
	10			16.5	--	0.6	19.1	14.8	51.					
	30				14.6	11.5	--	--	26.					
C. Page	3	305.			69.2	29.4	60.1	18.7	177.			107.	122.	76.
	10			32.4	--	24.0	24.9	20.9	102.					
	30				38.9	15.4	43.7	19.7	118.					
4. Glendale Coll.	8		245.											
Helicopter 1100 hrs	30	137.1												
	150	86.9												
	305	58.2												
Central														
1. Central Phoenix	10		108.							55.	94.	37.	54.	16.
3. Arizona Capitol	7		394.											
2. South Phoenix	10		315							87.	163.	110.	142.	63.

*Aerodynamic diameter size fractions
**Geometric diameter size fractions

( )Numbers in parentheses are microscopical estimates of mass

TABLE 21. MASS FLUX FOR 21 NOVEMBER, 1975

Height m	Conc. $\mu g/m^3$	Wind m/sec	Mass Flux $mg/sec\text{-}m^2$
Upwind			
0-6	242.	1.	.24
6-20	175.	1.	.18
20-50	91.	1.6	.15
50-200	43.	1.9	.08
200-350*	36.	2.3	.08
600.	27.		
Downwind			
0-6	228.	1.	.23
6-20	133.	1.	.13
20-50	94.	1.6	.15
50-200	87.	1.9	.17
200-350*	58.	2.3	.13
Central			
10.	243.		

* Inversion height.

The Track 11 downwind samples, collected 1.5 to 2 hours after the wind reversed direction, were more similar in composition to the early morning Track 11 samples than they were to the later morning downwind Track 1 samples. Recrystallized sulfate needles were higher in concentration than the Track 1 downwind samples. Particle sizes were also closer to those of the early morning Track 11 samples. At 30 m the bulk of the sample mass was in 8-16 μm particles; at 150 m the 5-15 μm size range contained most of the sample.

Upwind (East) Hi-Vol Filter Samples

Site 14. Paradise Valley Pumping Station, 433 $\mu g/m^3$

The sample consisted of primarily minerals (mostly feldspars) and clay aggregates. Mica and calcite were major sample components. Very few biological particles of any type were present. Automobile emissions were a major sample component. Both rubber tire particles and tailpipe emissions were present.

Approximately 45% of the sample by mass was contained in particles greater than 15 μm; 40% of the sample mass was in the 5-15 μm particles.

Very few clean-surfaced, highly angular, quartz particles were seen. The majority of the mineral particles had rounded edges, but were badly gouged and coated with other particles on the surfaces. Many of the carbonate particles showed signs of chemical attack.

Particle types were similar to those seen at the east sites, particularly the Indian Reservation. The clays and many of the minerals showed high iron content.

Site D. Indian Reservation, 182 $\mu g/m^3$

The sample was primarily small minerals (quartz, feldspars) and clay aggregates. Mica and calcite were present as major sample components. A few cotton fibers and spores represented a trace biological sample component. Automobile emissions were a minor sample component.

Overall, particle size was small. By mass, approximately 40% of the sample mass was present in particles greater than 15 μm. Approximately 50% of the sample mass was in the 5-15 μm range.

Large particles were rounded and were clay-coated. Very few clean, sharp particles were present.

Compared to the 17th, fewer particles in all size ranges accounted for the lower mass. The 21st sample was only slightly larger in particle size. Although the rubber tire dust particles were larger on the 21st, they were fewer in number. The fine carbonaceous particle concentration was higher in the sample of the 21st.

Site 8. Scottsdale, 179 $\mu g/m^3$

The sample was primarily large minerals (quartz, feldspars, mica) and clay aggregates. Biological particles were present in trace concentrations. Automobile emissions were a minor portion of the sample.

Particle size was fairly large. Approximately 65% of the sample mass was in the particles greater than 15 μm (most of that mass contained in particles greater than 30 μm). Approximately 25% of the sample mass was 5-15 μm particles.

Compared to the 17th, mica, clay aggregates, and the fine carbonaceous particles were present in higher concentrations. Rubber tire particles were larger but fewer in number compared to the 17th.

Particle size was larger compared to the Indian Reservation. Mineral type differences were the same between these two sites on the 21st as they were on the 17th.

Site 9. Mesa, 156 $\mu g/m^3$

The sample was primarily large minerals (quartz, feldspars, mica) and clay aggregates. Biological particles (mostly trichomes) were few in number. Automobile emissions -- mostly very large rubber tire particles -- were a major sample component.

Particle size was quite large. Approximately 70% of the sample mass was contained in the particles greater than 15 μm. Less than 5% of the sample mass was in the particles below 5 μm.

Most of the quartz and feldspar particles were clean and quite angular, as if they had been freshly cleaved.

Particle types were slightly different compared to the 17th. The fine carbonaceous material was much lower in concentration, while the clay aggregates were higher in concentration. Particle size was the major difference. All particle types showed much larger number (and therefore mass) mean diameters on the 21st compared to the 17th.

Site E. Mesa, 178 $\mu g/m^3$

Fine mineral particles (quartz, feldspars, calcite) were the primary sample components. Clay aggregates and discrete clay particles accounted for a minor portion of the sample. Few biological particles were seen. Rubber tire dust and fine carbonaceous material (tailpipe emissions) together were a major sample component.

Particle sizes were quite small. Approximately 40% of the sample mass was in particles greater than 15 µm with 50% of the mass in the 5-15 µm particle size range.

Few clean-surfaced, angular quartz or feldspar particles were seen. Most of the mineral particles had rounded edges and were coated with clay particles and fine carbonaceous debris.

The tower sample was quite different from the Mesa county (9) sample for this date. Both particle types and sizes made this sample more similar to the 17th Mesa tower sample.

Site F. Chandler, 433 $\mu g/m^3$

The sample consisted primarily of mineral particles and clay aggregates. Although biological particles were large and numerous (especially cornstarch particles), they represented only a trace of the sample mass. Automobile emissions were a minor component. A low efficiency incinerator contributed trace concentrations of partially burned paper fibers, carbonaceous flakes and balls, and glassy fly ash material.

Approximately 40% of the particles by mass were greater than 15 µm with 15% of the particles below 5 µm.

Except for a few quartz particles, the majority of the mineral particles showed rounded edges and were coated with clay and carbonaceous material.

This sample, except for the appearance of larger numbers of cornstarch particles, was identical in composition to the sample of the 17th.

Site 16. Chandler, 490 μg/m^3

The sample consisted primarily of quartz, feldspars, mica, and calcite. Clay aggregates were a major component as were automobile emissions.

Particle sizes were slightly larger than on the 17th. Except for this minor difference (and the presence of several cornstarch grains), the sample was identical to that of the 17th. As with the 17th samples, Chandler Site 16 showed larger particles and more automobile emissions than the Chandler F site.

Downwind (West) Hi-Vol Filter Samples

Site A. American Graduate School, 373 μg/m^3

The sample contained primarily minerals and clay aggregates. Biological particles were present in trace concentrations. Automobile emissions were a minor sample component.

The particle size was fairly large; approximately 45% of the sample by mass was contained in particles greater than 15 μm, with approximately 15% of the sample mass in the less than 5 μm particles.

While a few clean, angular quartz and feldspar particles were present, the bulk of the mineral particles showed rounded edges and highly gouged surfaces.

Compared to the 17th, the 21st sample showed slightly higher clay, iron, and total particle contents. Otherwise, the samples were quite similar in composition.

Site 4. Glendale Community College, 245 μg/m^3

The primary sample components were minerals -- feldspars, quartz, calcite, and mica. Small clay aggregates and clay particles were a major component. Biological particles were nearly absent. Automobile emissions were a major portion of the sample. The entire filter was coated with fine carbonaceous material. Recrystallized sulfate needles were a trace to minor component.

Particle sizes were quite small. Approximately 30% of the sample mass was in particles greater than 15 μm. The 5-15 μm size ranges contained 50% of the sample mass.

Few clean, angular, mineral particles were seen. Most of the particles were badly mangled.

The sample was quite different from the American Graduate School sample due to the high carbonaceous particle concentrations.

Site B. Parker, 182 μg/m^3

Small mineral particles and clay aggregates were the primary particle types. Few biological particles were present. The combined automobile emissions were a major component of the sample.

Particle sizes were quite small. Approximately 35% of the sample mass was in particles greater than 15 μm with the 5-15 μm range containing 50% of the sample mass.

Unlike the sample of the 17th, few clean, angular, quartz particles were present. Automobile emissions were also slightly higher in concentration than on the 17th. The smaller particle sizes accounted for the lower mass loadings seen on the 21st.

Site 5. West Phoenix, 263 μg/m^3

Approximately 40% of the sample mass was carbonaceous material almost exclusively due to automobile emissions. Quartz, feldspars, and clay aggregates together were the other primary sample component.

Mineral particle sizes were quite large. Approximately 40% of the sample mass was in particles greater than 15 μm and 25% in particles below 5 μm.

Many of the quartz particles were quite smooth and angular, indicating that they were freshly broken.

Carbonaceous particle concentrations increased significantly over the 17 November sample.

Site C. Page, 305 $\mu g/m^3$

The sample consisted primarily of small mineral particles -- feldspars, quartz, calcite, and mica. Clay aggregates were a major sample component. Biological particles (mostly trichomes) were a trace component. Automobile emissions were a minor component.

Particles were fairly small. By mass, 35% of the sample was represented by the particles greater than 15 μm. 50% of the mass was in the 5-15 μm particles.

Minerals tended to be rounded and clay-coated. Mica concentrations were lower and clay aggregate concentrations were slightly higher than those seen at American Graduate School on the 17th. This sample was much "cleaner" -- i.e., lower carbonaceous particle content -- than any other west sample for this date.

Central Hi-Vol Filter Samples

Site 1. Central Phoenix, 108 $\mu g/m^3$

The sample was composed primarily of quartz, feldspar, and mica particles. Clay aggregates were a minor component. Biological particles were a trace component. Automobile emissions were a major component.

Particle size was fairly small. Approximately 35% of the sample mass was in particles greater than 15 μm; 50% of the mass was contained in the 5-15 μm particles.

The sample was quite similar in composition to that of the 17th. Although particles were smaller on the 21st, many still tended to be clean and angular, as if freshly cleaved.

Site 3. Arizona State Capitol, 394 $\mu g/m^3$

Small quartz, feldspar, and calcite particles were the primary sample components. Clay aggregates were a major component. A few trichomes were the only biological particles present. Automobile emissions were a major sample component.

Approximately 40% of the sample mass was in the particles greater than 15 μm. 40% of the sample mass was distributed in the 5-15 μm particles.

Most of the quartz particles were clean and angular, indicating they had been freshly broken.

The sample showed much greater automobile influence than the Central Phoenix site. Sample composition was more comparable to most of the west sites for that date.

Site 2. South Phoenix, 315 μg/m^3

The sample was composed primarily of small quartz, feldspar, mica, and calcite particles. Clay aggregates were a minor sample component. Automobile emissions were a major sample component.

Approximately 40% of the sample by mass was distributed in the particles greater than 15 μm. The 5-15 μm particles constituted 50% of the sample mass.

Compared to the 17th, this sample showed a marked increase in urban air exposure. Carbonaceous material due to automobiles increased dramatically in concentration. Particle size was also smaller than on the 17th.

ELEMENTAL ANALYSES

Tables 22 and 23 present elemental concentrations, as determined by x-ray fluorescence, for the dichotomous samplers and Andersen final filters, respectively.

TABLE 22. X-RAY FLUORESCENCE ANALYSES OF DICHOTOMOUS SAMPLES FOR 21 NOVEMBER, 1975
Mass Percent

Sampling Sites	Stages*	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb	Sum
Upwind																											
D. Indian Res. 3 m																											
E. Mesa 3 m	F		3.6		4.4		0.7	1.1					1.0				.11	.18		.61						2.0	14.
	C	2.7	12.1		0.6	.08	1.5	5.2	0.3			.04	3.5			.06	.06	.04		.09		.04				0.1	26.
F. Chandler 3 m (Tower) 10 m (County)	F	1.7	7.0		2.3		1.2	1.7					1.9			.11	.10	.13		.41						1.1	18.
	C	3.4	11.6		0.5	.12	1.7	3.3	0.3			.05	3.1			.04	.03	.01		.04		.02					24.
8. Scottsdale 8 m																											
14. Paradise Valley 2 m																											
Downwind																											
A. Am. Grad. School 3 m																											
B. Parker 3 m																											
C. Page 3 m																											
4. Glendale Coll. 8 m																											
Central																											
1. Central Phoenix 10 m	F	0.8	3.2		2.8		0.6	1.1					1.1				.14	.03		1.4						4.3	16.
	C	2.5	12.4		.56	.13	1.4	4.7	0.3				3.6				.06	.04		.18		.04				0.26	26.
3. Arizona Capitol 7 m																											
2. South Phoenix 10 m	F	0.9	5.3		1.5	.2	1.0	1.8					1.7				.35	.09		1.3						3.8	18.
	C	4.2	17.8		0.71	.34	2.1	7.2	0.6			.1	5.4	.05		.03	.21			.15		.06				0.34	39.

*F=Fine Filter (<3.5 µm particles)
C=Coarse Filter (>3.5 µm particles)

TABLE 23. X-RAY FLUORESCENCE ANALYSES OF ANDERSEN FINAL FILTERS FOR 21 NOVEMBER, 1975
(Concentration, $\mu g/m^3$)

Site	Height m	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb
Grad School																										
Parker																										
	3						.20	.19					.44			.03	.09			.23						.78
	10																.04	.05		.42						1.2
	30																.04			.41						1.2
Page																										
	3				.77			.07					.14							.09						.4
	10				.95		.17	.15					.27				.03			.07						.3
	30				.88		.11	.16					.14							.04						.2
Indian Res.																										
	3																			.07						.22
	10																			.04						.19
	30												.27							.12						.60
Mesa																										
	3				.35													.05		.43						1.3
	10		.39		.33		.24	.54					.55			.05	.02	.06		.39						1.3
	30		.32													.05				.15						.6
Chandler																										
	3																.03									.1
	10				.71								.14			.05	.06	.04		.08						.3
	30				.78								.16			.06	.05	.02		.10						.4

SECTION 9

FOURTH SAMPLING PERIOD - SATURDAY, 22 NOV. 1975, NOON TO 5:00 P.M.

MASS FLUX DETERMINATIONS

Sampling was done only by helicopter. Only two pibal teams were in operation.

Another front was passing through. A strong wind from the east came up at 1030 or 1100 hrs, noticeably stirring up local dust at this time. However, visibility was good, and this was the clearest day we have seen. Pibal teams were in operation only at the Goodyear and Grad School sites. At Central Phoenix and Mesa, the County telemetry system recorded surface winds at 5 m/sec at 30° at 1030 hr, gradually decreasing to 1.5 m/sec at 1630 hr. Winds at Goodyear were higher, reaching 9 m/sec at 1230 hr, but decreasing to 1 m/sec at 1730 hr. Average wind profiles are shown in Tables 24 and 25.

Temperature profiles in Figure 8 show a strongly mixed isothermal zone up to 600 m at 1225 hr, with a more usual lapse rate at 1810 hr when the wind was less.

Helicopter data in Tables 26 and 27 show mass concentrations of 25 to 40 $\mu g/m^3$ at 30 m, and a few local peaks in the nephelometer traces upwind. Downwind values were similar. Nephelometer readings were low, indicating that most of the mass was in particles greater than 1 μm in size.

Mass concentrations are summarized in Table 27 and mass flux in Table 28. The values were not significantly different upwind and downwind of the city.

By late afternoon, the wind had died down. At 5:00 p.m., sampling was stopped. From the helicopter, we observed a dust plume from an auto on a dirt road, in very stagnant air due to inversion about 3-5 m deep, just as the sun was setting. The nephelometer registered 3.0 in a low pass.

TABLE 24. AVERAGE WIND PROFILE FOR 22 NOVEMBER, 1975
1200 to 1700 Hrs.

Vector Average			Arithmetic Average
Height m	Speed m/sec	Direction Degrees	Speed m/sec
surface	4.0	93.	
50	4.3	89.5	4.6
100	5.0	91.5	5.3
150	4.7	91.4	5.0
200	4.8	91.8	5.0
250	5.1	92.6	5.3
300	5.3	93.0	5.4
350	5.3	93.2	5.5
400	5.3	92.4	5.5
450	5.5	91.0	5.6
500	5.6	90.9	5.8
550	5.8	91.3	5.9
600	5.8	91.5	5.9
650	5.6	91.7	5.7
700	5.6	91.5	5.7
750	5.6	91.3	5.7
800	5.8	92.0	5.9
850	6.0	93.0	6.1
900	6.0	93.2	6.1
950	5.9	93.4	6.1
1000	6.0	93.3	6.1
1050	6.1	92.8	6.3
1100	6.4	91.4	6.5
1150	6.7	90.7	6.8
1200	6.8	90.4	6.9
1250	6.9	89.8	7.1
1300	7.0	88.9	7.3
1350	7.6	83.7	7.8
1400	8.0	79.1	8.3
1450	8.0	78.8	8.2
1500	8.0	79.3	8.2
1550	8.1	78.2	8.3
1600	8.1	77.1	8.3
1650	7.9	76.1	8.1
1700	7.7	74.7	7.9
1750	7.1	72.7	7.6
1800	7.4	71.8	7.6
1850	7.3	71.2	7.5
1900	6.7	71.6	6.9
1950	9.1	60.3	9.1
2000	6.8	63.2	6.8

TABLE 25. WIND PROFILES AT PILOT BALLOON SITES FOR 22 NOVEMBER, 1975
Vector Averages

Height m	Goodyear Speed m/sec	Goodyear Dir. Degrees	Grad School Speed m/sec	Grad School Dir. Degrees
	4.	93.		
50	5.1	76.9	3.5	[illegible]
100	5.7	81.8	4.5	105.1
150	5.7	83.9	3.9	103.4
200	5.9	85.9	3.6	102.3
250	6.4	87.4	3.6	102.1
300	6.5	87.6	4.1	102.1
350	6.3	87.7	4.2	[illegible]
400	6.4	87.2	4.3	[illegible]
450	6.5	86.5	4.4	[illegible]
500	6.6	86.5	4.4	[illegible]
550	7.0	86.9	4.5	[illegible]
600	7.0	87.6	4.5	[illegible]
650	6.8	88.5	4.3	97.2
700	6.7	89.5	4.3	94.0
750	6.7	90.6	4.4	92.5
800	7.0	93.2	4.5	91.2
850	7.3	95.8	4.5	87.9
900	7.3	96.9	4.6	86.7
950	7.2	97.7	4.6	85.9
1000	7.3	97.0	4.6	86.8
1050	7.4	95.9	4.6	87.8
1100	7.6	93.6	5.1	87.8
1150	7.8	93.1	5.5	87.0
1200	7.7	93.9	5.6	85.5
1250	7.8	92.9	6.0	85.5
1300	7.9	91.2	6.0	85.4
1350	8.3	86.7	7.0	77.1
1400	8.6	86.5	7.5	69.9
1450	8.4	85.1	7.7	71.2
1500	8.2	83.6	7.7	73.7
1550	8.2	82.3	8.0	73.1
1600	8.0	81.7	8.2	71.8
1650	7.7	81.7	8.2	69.7
1700	7.7	79.7	7.7	68.7
1750	7.3	76.5	7.0	56.0
1800	8.1	73.9	6.5	46.7
1850	8.4	72.2	5.9	49.5
1900	7.9	72.1	5.2	70.7
1950	9.1	60.3	.0	.0
2000	6.8	43.2	.0	.0

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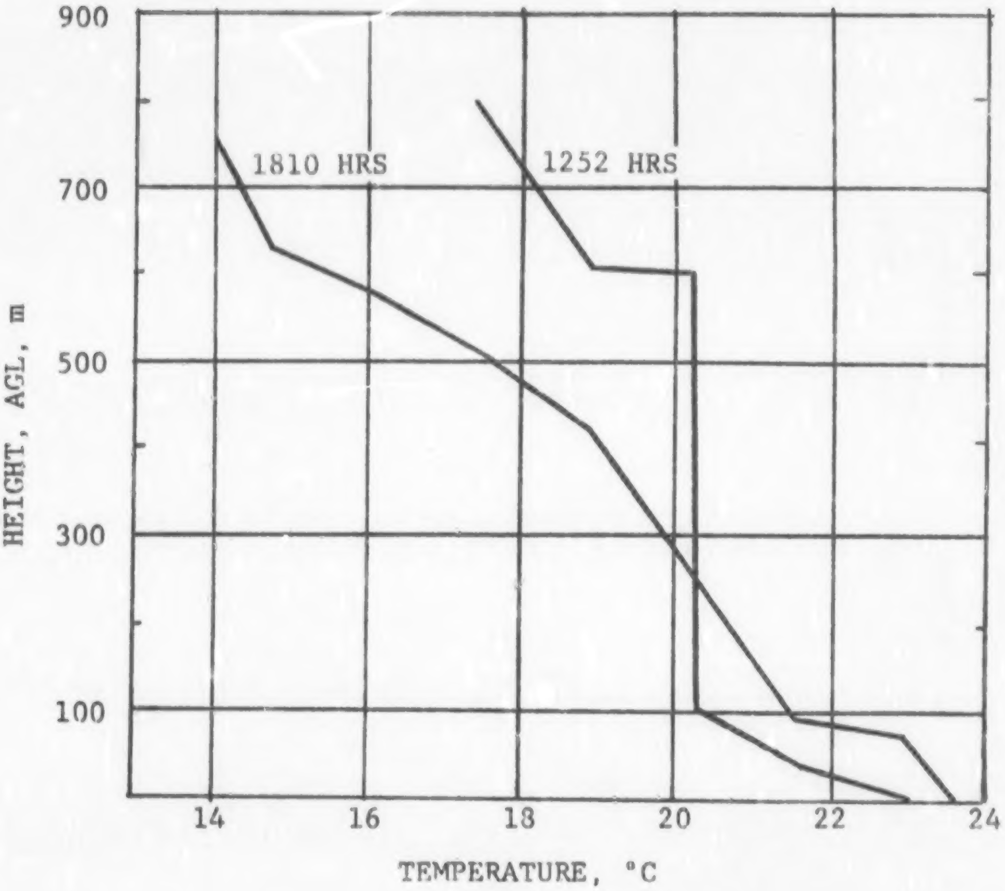

Figure 8. Height vs. Temperature, 22 November, 1975.

TABLE 26. HELICOPTER SAMPLING DATA FOR 22 NOVEMBER, 1975

Track	Time, min start	Time, min Δ	Altitude ft	Altitude m	Filter No.	Wt, μg	Flow, m^3	Conc, $\mu g/m^3$	Nephelometer, Volts** (Position in Track) N	Midpoint	S	Average
East - Upwind												
11	1239	19	100	30	117508	<305	11.83	<25.8		not operating		-
11	1300	18	300	90	117502	(100)	11.21	(9.)	1.1	1.2	1.3	1.2
11	1321	18	1000	305	117507	(200)	11.21	(18.)	1.1	1.1	1.2	1.1
West - Downwind												
1	1400	15	300	90	117504	(50)	9.34	(5.)	1.1	1.2	1.2	1.2
1	1418	16	100	30	117503	(400)	9.96	(40.)	1.1	1.2	1.2	1.2
1	1624	15	100	30	117520	(175)	9.34	(19.)	-	-	-	-
1	1642	16	100	30	117505	(350)	9.96	(35.)	-	1.1	1.3	1.2
1	1700	15	1000	305	117509	141	9.34	15.1	1.1	1.1	1.1	1.1

**The nephelometer responds to μm-sized particles, not to the full range of sizes collected by the samplers. The table shows the shape of the nephelometer trace and the average readings at ends and midpoint of each helicopter run.

( )Numbers in parentheses represent microscopical estimates of mass

TABLE 27. MASS CONCENTRATIONS FOR 22 NOVEMBER, 1975

		Hi-vol $\mu g/m^3$
Upwind		
Helicopter, 1300 hrs	30 m	25.8
	90 m	(9.)
	305 m	(18.)
Downwind		
Helicopter, 1400 hrs	30 m	(40.)
	90 m	(5.)
1630 hrs	30 m	(19.)
	30 m	(35.)
	1,000 m	15.1

( )Numbers in parentheses are microscopical estimates of mass

TABLE 28. MASS FLUX FOR 22 NOVEMBER, 1975

Height, m	Conc. $\mu g/m^3$	Wind, m/sec	Mass Flux, $mg/sec\text{-}m^2$
Upwind			
20-50	26.	4.	.10
50-500	(14.)	5.	(.07)
Downwind			
20-50	(31.)	4.	(.12)
50-500	(10.)	5.	(.05)

MICROSCOPIC PARTICLE CHARACTERIZATIONS

Upwind Helicopter Samples

The upwind Track 11 samples were lightly loaded, primarily with small mineral particles and clays. The 30 and 90 m samples showed very low concentrations of rubber tire dust and tailpipe emissions; these materials increased in concentration in the 305 m sample, but still constituted only a minor component. Recrystallized sulfate needles increased from a minor to a major component with increasing altitude.

Particle size decreased slightly with increasing altitude. The bulk of the sample mass at 30 m was in 10-25 μm particles, and at 90 m and 305 m in the 5-15 μm particles.

Downwind Helicopter Samples

The downwind Track 1 samples showed increased concentrations of calcite, rubber tire dust, and clay compared to upwind samples taken at the same altitude. Recrystallized sulfate concentrations were lower than the upwind samples, but showed increasing concentration with increasing altitude, as did the upwind samples.

Particle size was a major difference between upwind and downwind samples, especially at the higher altitudes. At 305 m the bulk of the downwind sample mass was in the 10-20 μm particle size range.

SECTION 10

FIFTH SAMPLING PERIOD - SUNDAY NIGHT, 23 NOV. 1975 to MONDAY, 24 NOV. 1975

MASS FLUX DETERMINATIONS

The purpose of this sampling period was to determine whether measurements made at night would reveal any new features of particle origin and transport. Very strong inversion was expected. The helicopter was above the inversion measuring the background of particles brought from greater distance or remaining in the higher air mass from the previous day's emissions.

The upper winds were rather strong from the northeast, much higher than usual for Phoenix. Average wind data are shown in Tables 29 and 30. At some sites, a layer of NW winds prevailed from 100 to 300 m, but this was averaged out in the tables.

The temperature profile in Figure 9 showed a strong inversion up to 120 m; then it was isothermal to 220 m. Above 300 m, the prevailing wind was NE. By midnight, the wind was mostly 2 m/sec from 30° (NE) at all heights, and there was some mixing of the inversion up to 300 m as shown in Figure 9.

At the County Building the balloon rose straight up for the first 7 m above the roof (10 m roof height), suggesting a strong but shallow inversion, with northeast wind direction above this. Alternatively, this behavior could represent a slower ground wind speed in the city due to the roughness effect of buildings.

These wind patterns are not typical of Phoenix nights. The usual drainage winds were only sporadically observed in some Pibal measurements. Synoptic wind from the northeast is unusual, and it accounts for the very clear night that was observed. In spite of this, the hi-vols at the central sites were very black with particulates from auto emissions caught in the low inversion

TABLE 29. AVERAGE WIND PROFILE FOR 23-24 NOVEMBER, 1975
2200 to 0600 Hrs

Vector Average			Arithmetic Average
Height m	Speed m/sec	Direction Degrees	Speed m/sec
50	3.5	47.6	3.9
100	4.9	46.2	5.4
150	4.9	44.8	5.4
200	5.0	44.2	5.6
250	5.7	45.7	6.4
300	6.3	46.5	6.8
350	6.6	47.7	7.0
400	6.9	49.5	7.1
450	7.1	51.9	7.2
500	7.3	54.0	7.4
550	7.6	55.9	7.7
600	7.6	56.8	7.7
650	7.4	57.3	7.6
700	7.3	57.6	7.4
750	7.0	57.7	7.1
800	7.0	58.3	7.1
850	7.1	59.0	7.2
900	6.9	59.3	7.1
950	6.8	59.2	7.0
1000	6.5	57.3	7.1
1050	6.6	55.4	7.3
1100	7.2	56.8	7.3
1150	7.6	57.5	7.7
1200	8.3	57.9	8.4
1250	8.2	57.3	8.4
1300	7.9	55.9	8.1
1350	7.8	55.8	8.1
1400	7.9	55.4	8.1
1450	7.9	51.4	8.2
1500	7.8	50.0	8.1
1550	8.0	49.2	8.4
1600	8.2	47.8	8.6
1650	8.3	45.0	8.6
1700	8.1	42.5	8.4
1750	7.8	39.7	8.1
1800	7.5	36.4	7.8
1850	7.2	33.1	7.5
1900	7.2	29.9	7.4
1950	7.1	26.9	7.2
2000	8.2	25.3	8.4

TABLE 30. WIND PROFILES AT PILOT BALLOON SITES FOR 23-24 NOVEMBER, 1975
Vector Averages

Height m	Central		Mesa		Goodyear		Grad School	
	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees
50	1.6	59.1	5.7	34.4	2.9	64.7	4.5	47.2
100	2.4	50.1	8.2	38.8	3.9	63.0	5.9	42.6
150	2.3	42.3	8.3	44.2	4.1	59.4	5.5	36.1
200	2.5	43.4	9.1	50.0	3.0	55.2	5.5	32.4
250	2.9	45.1	10.8	53.7	3.6	50.3	6.0	31.9
300	3.5	48.9	10.5	55.3	4.8	45.3	6.7	33.7
350	4.1	53.3	9.7	56.8	5.9	41.5	7.3	37.1
400	4.8	54.2	9.5	58.8	6.1	42.8	7.5	39.4
450	5.6	55.2	9.5	60.9	5.7	46.6	7.4	41.8
500	6.2	55.7	9.6	62.3	6.2	48.7	7.3	45.9
550	6.6	55.7	9.7	63.3	7.2	49.5	6.9	51.3
600	7.1	55.3	9.5	63.0	7.6	50.6	6.5	55.2
650	7.5	54.9	9.1	61.8	7.6	52.0	5.9	58.7
700	8.0	55.0	8.3	60.2	7.6	54.4	5.5	60.6
750	8.4	55.2	7.3	58.0	7.6	57.3	5.1	61.6
800	8.5	55.3	6.6	57.8	8.3	60.4	5.1	62.0
850	8.6	55.3	6.1	58.2	8.9	62.9	5.2	61.8
900	8.5	55.7	5.7	57.8	8.9	62.9	5.3	62.5
950	8.4	55.7	5.3	56.9	8.8	62.5	5.3	63.3
1000	7.2	51.2	5.6	54.7	8.9	61.1	5.3	63.9
1050	7.3	46.6	5.9	53.6	9.0	60.4	5.3	63.6
1100	8.3	52.5	6.8	53.5	8.8	61.8	5.4	61.9
1150	8.8	56.3	7.4	54.6	9.3	60.0	5.5	60.2
1200	10.3	59.9	7.8	56.6	10.3	55.6	5.5	58.6
1250	10.1	58.1	7.8	55.8	10.3	57.1	5.4	57.7
1300	9.2	53.5	7.7	53.6	10.0	61.0	5.3	56.9
1350	9.0	52.7	7.6	55.7	10.5	61.4	5.3	54.3
1400	8.9	52.1	7.5	56.6	10.9	61.3	5.4	51.5
1450	8.8	49.9	8.2	46.7	10.6	61.1	5.2	47.8
1500	8.8	47.9	8.1	45.8	10.4	60.7	5.2	45.0
1550	9.0	46.6	8.0	45.9	10.4	60.1	5.5	44.4
1600	9.1	46.8	9.0	43.4	10.1	58.8	5.6	42.5
1650	8.9	48.5	10.3	35.5	9.8	56.7	5.5	39.6
1700	8.6	46.4	10.3	34.4	9.1	55.1	5.7	35.1
1750	8.1	42.4	9.8	35.1	6.2	53.5	5.6	29.7
1800	8.2	38.3	8.8	31.5	7.6	51.1	6.1	28.3
1850	8.0	35.2	7.9	26.3	6.4	38.0	6.5	27.2
1900	7.5	32.7	7.8	22.4	7.1	43.4	6.7	24.7
1950	3.5	7.3	.0	.0	11.0	33.0	.0	.0
2000	4.5	2.8	.0	.0	12.4	33.3	.0	.0

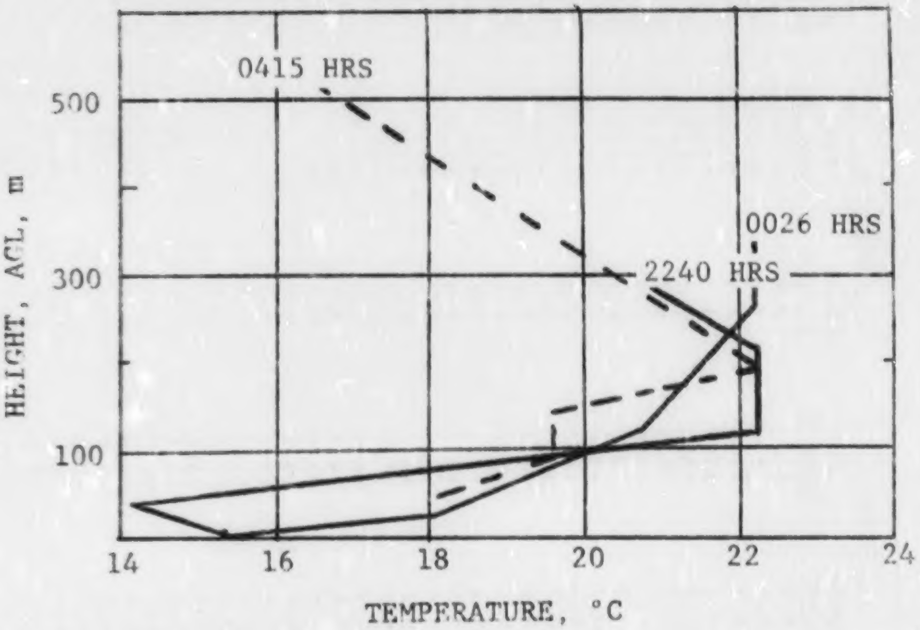

Figure 9. Height vs. Temperature, 23-24 November, 1975.

layer. Table 31 shows that carbon monoxide levels were also highest at these sites (last 3 columns of the table).

Helicopter mass data are shown in Table 32. Mass measurements were unreliable due to difficulties of operating at night and resulting damage to the filters, etc. However, it was possible to estimate the mass loadings on the filters during the microscopic examination by comparing the number of particles of various size ranges to those on other helicopter filters that appeared to be in good condition and had reasonable weights. These estimates are shown in parentheses in the tables. In Table 32, the nephelometer showed low values, which is reasonable since it was flying above the inversion height, being limited to flying above 500 ft at night.

Mass concentrations are summarized in Table 33. Mass flux data are presented in Table 34. Below 50 m, the mass flux was higher downwind than upwind (e.g., 149 $\mu g/m^3$ compared to 81 $\mu g/m^3$ at 3 m height). The values above 50 m were also higher downwind, but the difference is probably not significant.

MICROSCOPIC PARTICLE CHARACTERIZATIONS

Upwind Helicopter Samples

The two Track 10A (north) samples contained primarily fine mineral particles and recrystallized sulfate needles. Tailpipe emissions constituted a minor portion of each sample. Tailpipe emissions and sulfate concentrations increased with increasing altitude. Particle size decreased slightly with increasing altitude. The bulk of mass on each sample was in the 5-10 μm particle size range.

The two Track 9 (northeast) samples were slightly different in composition from the Track 10A samples. More calcite and clay particles were present in the Track 9 samples. The tailpipe emissions were also present in greater concentration, although they were still a minor sample component. Sulfate concentrations, which constituted a major sample component, were present in lower concentrations. Component composition did not vary with increasing altitude as it did in the Track 10A samples. Particle sizes were comparable to the 10A samples, showing decreasing particle size with increasing altitude.

TABLE 31. CARBON MONOXIDE CONCENTRATIONS FOR 23-24 NOVEMBER, 1975

	Station						
Hour	9. Mesa	8. Scottsdale	N. Phoenix	4. Glendale	1. Central	2. South	3. Capitol
0900	2.9	6.6	7.1	5.3	12.9	6.0	12.5
1000	0	3.0	5.9	5.0	14.6	4.3	16.8
0100	0	2.0	1.9	1.6	13.7	4.2	10.5
0200	0	1.5	1.5	2.2	14.5	4.9	7.9
0300	0	.5	2.0	3.2	11.0	3.2	11.6
0400	0	0	1.2	1.7	8.0	6.6	11.2
0500	-	-	-	-	5.7	8.0	10.2
0600	0	0	0.9	1.2	4.8	2.8	9.1
8 Hr. Av.	-	1.0	2.0	2.0	10.8	4.7	12.1

Data Courtesy of Maricopa County Telemetry Network

TABLE 32. HELICOPTER SAMPLING DATA FOR 23-24 NOVEMBER, 1975

Track	Time, Start	min Δ	Altitude ft	m	Filter No.	Wt, μg	Flow, m^3	Conc. $\mu g/m^3$	Nephelometer, Volts** (Position in Track)			Average
North-Upwind									W	Midpoint	E	
10A	2300	14	1200	365	117514	(175.)	8.72	(20.)	1.1 —	1.1 —	1.1	1.1
10A	2318	17	500	150	117513	128	10.58	12.1	1.0 —	1.3 —	1.4	1.4
Northeast-Upwind									NW	Midpoint	SE	
9	423	19	1200	365	117510	(175.)	11.83	(15.)	1.1 —	1.1 —	1.1	1.1
9	444	18	500	150	117549	(150.)	11.21	(13.)	1.1 —	1.1 —	1.2	1.1
South-Downwind									W	Midpoint	E	
4	2348	17	500	150	117516	(100)	10.58	(9.)	1.5 —	1.5 —	1.5	1.5
4	0007	18	1200	365	117511	(200)	11.21	(18.)	1.4 —	1.4 —	1.4	1.4
Southwest-Downwind									NW	Midpoint	SE	
3	0519	9	1200	365	117552	(200)	5.60	(36.)	1.1	———	1.2	1.1
3	0531	7	500	150	117501	(150)	4.36	(34.)	1.1	———	1.1	1.1

**The nephelometer responds to μm-sized particles, not to the full range of sizes collected by the samplers. The table shows the shape of the nephelometer trace and the average readings at ends and midpoint of each helicopter run.

( )Numbers in parentheses represent microscopical estimates of mass

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TABLE 33. MASS CONCENTRATIONS FOR 23-24 NOVEMBER, 1975

	Height m	Mass Concentrations, µg/m³												
		Hi-vol		Andersen*						Dichotomous*		Hi-vol (Microscope Est.**)		
		Tower	County	>25 µm	>15 µm	>8 µm	>2.5 µm	>0.9 µm	Sum	Fine <3.5µm	Coarse >3.5µm	>15 µm	5-15 µm	<5 µm
Upwind														
D. Indian Res.	3	129.			25.0	4.3	21.4	6.6	57.3			45.	65.	19.
	10				4.6	4.4	34.4	5.4	48.6					
	30			0.6	--	--	3.9	15.8	20.5					
E. Mesa	3	70.	56.		15.5	7.1	3.5	--	26.1	19.	34.			
	10				8.0	3.3	--	--	11.3					
	30			21.9		12.1	7.1	--	41.1					
14. Paradise Valley	2		128.											
8. Scottsdale	8		142.							47.	75.	64.	57.	21.
A. Am. Grad. School	3	109.			17.3	12.8	31.3	8.7	70.1			22.	65.	22.
	10				23.2	8.2	17.6	10.7	59.7					
	30			9.2		12.3	6.0	41.9	69.4					
4. Glendale Coll.	8		111.											
Helicopter 2300 hrs	150	12.1												
	365	(20.)												
Helicopter 0400 hrs	150	(13.)												
	365	(15.)												
Downwind														
F. Chandler	3	234.												
	10		263.							65.	77.			
	30													
C. Page	3	151.			11.2	20.4	18.8	11.6	62.			30.	91.	30.
	10			7.1		12.4	28.8	23.6	71.9					
	30				19.9	6.2	14.9	20.7	61.7					
2. South Phoenix	10		116.							43.	63.	52.	46.	17.
Helicopter 2400 hrs	150	(9.)												
	365	(18.)												
Helicopter 0500 hrs	150	(34.)												
	365	(36.)												
Central														
1. Central Phoenix	10		162.									49.	81.	8.
2. Arizona Capitol	7		194.											
5. West Phoenix	6		134.							74.	39.			
B. Parker	3	156.		21.6		19.3	--	13.0	53.9					
	10			22.7			11.4	22.8	56.9					
	30				10.2	14.7		11.8	36.7					

*Aerodynamic diameter size fractions
**Geometric diameter size fractions

( )Numbers in parentheses are microscopical estimates of mass

TABLE 34. MASS FLUX FOR 23-24 NOVEMBER, 1975

Height m	Conc. $\mu g/m^3$	Wind m/sec	Mass Flux $mg/sec\text{-}m^2$
Upwind			
0-6	81.	1.	.08
6-20	82.	2.	.16
20-50	44.	3.	.13
50-200	13.	4.9	.06
200-1000	(18.)	7.	(.13)
Downwind			
0-6	149.	1.	.15
6-20	140.	2.	.28
20-50	(62.)	3.	(.19)
* 50-200	(22.)	4.9	(.11)
200-1000	(27.)	7.	(.19)
Central			
0-6	(105.)		
6-20	132		

*Inversion Height

Downwind Helicopter Samples

The two Track 4 (south) samples were compared to the Track 10A (upwind) samples. As with the upwind samples, very fine minerals constituted the bulk of the sample. While recrystallized sulfate needles and tailpipe emissions represented the next most abundant species, the concentrations of these materials were lower than at the corresponding upwind altitudes and did not tend to change with altitude. Particle size was slightly smaller than the upwind samples and also did not change with altitude.

The two Track 3 (southwest) samples were different from the Track 4 downwind samples and the Track 9 upwind samples to which they corresponded. Carbonaceous particle (tailpipe emissions) and recrystallized sulfate needle concentrations were higher in the southwest than in the south downwind samples. Compared to the northeast upwind samples, the southwest downwind samples showed higher sulfate needle and lower carbonaceous particle (tailpipe emissions) concentrations, especially with increasing altitude. Particle sizes were slightly smaller for the southwest downwind sample compared to the northeast upwind sample.

Upwind (North) Hi-Vol Filter Samples

Site A. American Graduate School, 109 $\mu g/m^3$

The sample was composed primarily of small quartz and feldspar particles. Clay aggregates were a major sample component. Biological particles were few in number. Automobile emissions were a minor to major component.

Particle size was small: approximately 25% of the sample mass was in particles greater than 15 μm. Over 60% of the sample mass was contained in the 5-15 μm range.

The large quartz particles tended to be clean and angular, as if freshly broken. Smaller mineral particles also tended to be fairly angular.

The carbonaceous particle content of the sample was surprisingly low. The sample was similar in composition to the 17 November sample, with lower loadings of all materials.

Site 4. Glendale Community College, 111 μg/m^3

The sample was composed primarily of large quartz, feldspar, calcite, and mica particles. Clay aggregates were a major component. Automobile emissions were a minor sample component. Particle size was large. Approximately 40% of the particles by mass were greater than 15 μm with 50% of the particles in the 5-15 μm range.

Less than 20% of the mineral particles were clean and angular. The majority showed rounded edges and were coated with clays.

While carbonaceous particles were present in large numbers, the large mineral size reduced the effective carbonaceous particle loadings to minor levels. Compared to the sample collected on the 21st, the night sample showed a lower percentage of carbonaceous material.

Site 14. Paradise Valley Pumping Station, 128 μg/m^3

The sample was nearly identical in composition to the sample collected on the 21st. The 23rd sample showed slightly lower loadings of carbonaceous material (i.e., rubber tire dust and tailpipe emissions). Particle size was not significantly smaller than on the 21st.

Site D. Indian Reservation, 129 μg/m^3

The sample was composed primarily of large clay aggregates and slightly smaller mineral particles. Biological particles (trichomes and cotton fibers) were trace components. Automobile emissions were trace to minor sample components.

Particle size was quite large, especially for the clay aggregates. Approximately 50% of the particles by mass were greater than 15 μm.

Except for slightly higher concentrations of fine carbonaceous material, the sample was identical to the sample collected on the 25th. Mineral and clay concentrations were higher than on the 21st.

Downwind (South) Hi-Vol Filter Samples

Site C. Page Residence, 151 μg/m^3

The sample was quite similar in composition to the sample collected on the 21st, except for higher concentrations of fine carbonaceous materials (tailpipe emissions). The particles were slightly smaller than on the 21st. Approximately 50% of the sample mass was in the 5-15 μm particles, with 30% larger than 15 μm.

Site 2. South Phoenix, 116 $\mu g/m^3$

The sample was nearly identical to the sample collected on the 21st; lower loadings of all materials resulted in the lower mass concentration for the 23rd.

Particle size was larger on the 23rd compared to the 21st due to the presence of more particles greater than 15 μm. Approximately 45% of the sample by mass was in particles greater than 15 μm. Particles below 5 μm accounted for approximately 15% of the sample mass.

Site F. Chandler, 234 $\mu g/m^3$

The fine carbonaceous material (tailpipe emissions) concentration was elevated and overall particle size was decreased compared to other samples for this site. The smaller particle size, along with lower loadings of all materials, accounted for the lower mass concentration for the sample. Approximately 30% of the sample mass was contained by particles greater than 15 μm with 50% of the mass in the 5-15 μm range.

Site 16. Chandler, 263 $\mu g/m^3$

Compared to the tower site, the county sample showed fewer clay aggregates, slightly lower concentrations of fine carbonaceous material, high numbers of clean, angular quartz, and an overall larger particle size. Approximately 45% of the sample mass was contained in particles greater than 15 μm. The very large rubber tire particles and freshly-fractured quartz particles suggested a local traffic influence.

Central Hi-Vol Filter Samples

Site B. Parker Residence, 156 $\mu g/m^3$

The sample was composed primarily of fine quartz, feldspar, and calcite particles. Small clay aggregates were a major sample component. Automobile emissions were also a major portion of the sample.

Particle size was quite small. By mass, approximately 30% of the sample particles were greater than 15 μm and 50% were in the 5-15 μm range.

The sample was fairly similar in composition to the one collected on the 21st. Fine carbonaceous particle concentrations were higher and overall particle sizes were smaller on the sample collected on the 23rd.

Site 5. West Phoenix, 134 μg/m^3

Approximately 20% of the sample mass was carbonaceous material, most of which was due to automobile emissions. The remainder of the sample was primarily small mineral particles -- quartz, feldspars, calcite -- and some clay aggregates. Approximately 30% of the sample by mass was in particles greater than 15 μm.

Site 1. Central Phoenix, 162 μg/m^3

Approximately 25% of the sample mass was carbonaceous material from automobile emissions. Quartz and feldspar particles were the primary sample components, with clay aggregates (more similar in composition to those seen at the west vs. the east sites) a major component.

Particle sizes were quite small. Approximately 30% of the sample mass was contained in particles greater than 15 μm while particles less than 5 μm represented 20% of the sample mass.

The sample was most similar to the sample of the 21st for this site. As with the 21st sample, automobile emission concentrations were high. On the 23rd, there was a higher percentage of fine carbonaceous material and a much smaller particle size.

Site 3. Arizona State Capitol, 194 μg/m^3

Approximately 35% of the sample mass was carbonaceous material from automobile emissions. Quartz, feldspars, and clay aggregates were the other major sample components. Larger particle sizes for both the minerals and rubber tire particles were seen compared to the previous two central sites described. By mass, 40% of the sample mass was contained in particles greater than 15 μm. Compared to the sample collected at this site on the 21st, overall particle size was smaller and the fine carbonaceous particle concentration was higher on the 23rd.

Site 8. Scottsdale, 142 μg/m^3

The sample was slightly different than any of the other samples collected at this site. Fine carbonaceous material was present in slightly higher concentrations and particle sizes were smaller. The sample was still primarily quartz, feldspar, and mica particles with major concentrations of clay aggregates and automobile emissions.

By mass, approximately 30% of the sample was contained in particles greater than 15 μm. 55% of the particles were in the 5-15 μm range.

A local source for the automobile emissions was indicated by the presence of very large rubber tire particles.

Site 9. Mesa, 56 μg/m^3

This sample was typical of all samples collected at this site -- primarily very large, sharp, clean mineral particles with large rubber tire particles as a major component. Fine carbonaceous particle concentrations were slightly higher than on the other sampling days. By mass, approximately 60% of the sample was in particles greater than 15 μm, and 30% was in the 5-15 μm range.

Again, a local automobile emissions source was indicated by the very large particles present.

Site E. Mesa, 70 μg/m^3

As with previous sampling days, this sample contained smaller, less angular particles than the Mesa 9 site. However, the concentration of fine carbonaceous material was lower at E compared to 9, which was not normally the case. The higher mass concentration at E compared to 9 was due to the presence of many more particles in the 5-15 μm range. Approximately 50% of the sample mass was contained in the 5-15 μm particles.

ELEMENTAL ANALYSES

Tables 35 and 36 present elemental concentrations, as determined by x-ray fluorescence, for the dichotomous samples and Andersen final filters, respectively.

TABLE 35. X-RAY FLUORESCENCE ANALYSES OF DICHOTOMOUS SAMPLES FOR 23-24 NOVEMBER, 1975
Mass Percent

Sampling Sites	Stages*	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb	Sum
Upwind																											
D. Indian Reservation 3 m																											
E. Mesa 3 m 10 m	F		2.3		4.9		0.5	0.6					0.6					.11		.50						1.2	11.
	C	2.0	10.1		0.3		1.1	3.4					2.5							.09							26.
14. Paradise Valley 2 m																											
8. Scottsdale 8 m	F	1.5	6.3		2.0		1.2	1.5					1.8					.08		1.2						3.1	19.
	C	4.1	13.6		0.4	.12	1.6	4.3	0.3			.05	3.7					.02		.18		.04				.32	29.
A. Amer. Grad. School 3 m																											
4. Glendale Coll. 8 m																											
Downwind																											
F. Chandler 3 m 10 m	F	2.8	9.6		2.9		1.6	2.3	0.2				2.4			.12	.04	.07		.28						1.1	23.
	C	4.3	14.8		0.6	.17	1.9	3.8	0.3				3.6			.03	.02	.015		.05		.03					30.
C. Page 3 m																											
2. South Phoenix 10 m	F	1.2	5.3		2.5		1.1	1.7					1.1				.06	.16		1.9						5.0	20.
	C	3.2	14.3		0.5	.18	1.7	5.0	0.3				3.4				.04	.04		.18		.04				.34	29.
Central																											
1. Central Phoenix 10 M	F																	.22		1.02						1.7	3.
	C		3.1		1.1			.96					0.8							1.7							
3. Arizona Capital 7 m																											
5. West Phoenix 6 m	F		2.6		1.3	.19	0.8	0.9					0.8				.06	.21		2.7						6.6	16.
	C	3.6	12.7		0.5		1.5	4.1	.27				3.1				.24	.03		.35		.04				.74	27.
B. Parker																											

*F=Fine Filter (<3.5 μm particles)
C=Coarse Filter (>3.5 μm particles)

TABLE 36. X-RAY FLUORESCENCE ANALYSES OF ANDERSEN FINAL FILTERS FOR 23-24 NOVEMBER, 1975
(Concentration, $\mu g/m^3$)

Site	Height m	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb
Grad School	3				.19															.08						.24
	10				.20															.07						.21
	30				.20												.05									.04
Parker	3																			.30						.82
	10						.11									.04				.45						1.3
	30																			.29						.84
Page	3				.35		.26	.5					.31			.02				.26						.81
	10				.32		.11	.15					.09					.02		.31						.84
	30				.31		.10	.12					.15			.03	.03	.01		.27						.91
Indian Res.	3				.17								.06			.02				.07						.27
	10				.12															.03						.13
	30												.16			.06				.03						.13
Mesa	3			.11	.29															.07						.26
	10				.21	.06	.08						.18			.03				.05						.22
	30				.13											.03				.014						.05

SECTION 11

SIXTH SAMPLING PERIOD - TUESDAY, 25 NOV. 1975, 6:00 A.M. TO NOON

MASS FLUX DETERMINATIONS

This was a normal Phoenix morning except that a light high cloud layer reduced the normal insulation and resulted in a slightly reduced ground heating.

Average wind data are given in Tables 37 and 38. At 0730 hr, the drainage wind was weak at the surface (1 m/sec from 65 to 90°) but strong 3-5 m/sec) from E above 50 m. The temperature profile (Figure 10) showed a strong inversion up to 130 m. From this height to 350 m, the winds were still in the drainage direction, 2-4 m/sec from 100-160° (SE), and the isothermal temperature profile showed strong mixing. Above [illegible]0 m, the synoptic wind ranged from 2 to 10 m/sec from 220 to 300° (W).

Visual observation from South Mountain showed a strong inversion with brown pollution below a sharp layer at about the level of the foothills of South Mountain, or 150 m above the valley floor. At 0900 hrs, there appeared to be some mixing of haze above this, but the demarcation line was still sharp. Carbon monoxide concentrations are shown in Table 39.

Helicopter sampling data given in Table 40 showed moderate concentrations at 0800 hr (25-45 $\mu g/m^3$ at 30 m). The nephelometer registered sharp peaks at some locations where a brown cloud of urban pollution was seen.

Later in the morning, at 1000 to 1100 hrs, the temperature profile (Figure 10) was warmer up to 150 m, with the weak inversion persisting to 500 m. The wind direction showed a gradual shift from 90° at the surface to 330° above 500 m, as shown in Table 9.

Some of the helicopter runs over Track 1 were done at high elevations to measure any particles that might be carried in with the synoptic wind from the

TABLE 37. AVERAGE WIND PROFILE FOR 25 NOVEMBER, 1975
0700 to 1130 Hrs.

Vector Average			Arithmetic Average
Height m	Speed m/sec	Direction Degrees	Speed m/sec
50	1.9	104.8	2.4
100	2.4	114.5	3.1
150	2.2	127.6	3.0
200	2.1	136.9	2.6
250	1.9	144.3	2.3
300	1.7	151.2	2.0
350	1.2	167.6	1.7
400	.8	189.9	1.6
450	.7	236.8	1.8
500	1.0	265.7	2.0
550	1.3	285.5	2.2
600	1.7	293.8	2.5
650	2.1	301.1	2.8
700	2.7	302.9	3.2
750	3.2	305.6	3.6
800	3.7	303.8	4.0
850	3.9	302.6	4.4
900	4.8	303.1	5.1
950	5.4	304.6	5.6
1000	5.9	302.6	6.1
1050	6.5	301.8	6.7
1100	7.1	303.2	7.3
1150	7.5	303.9	7.6
1200	7.9	305.1	8.0
1250	8.0	306.6	8.1
1300	8.0	308.5	8.2
1350	8.2	310.1	8.4
1400	8.5	312.2	8.7
1450	8.8	315.3	9.0
1500	9.0	317.0	9.3
1550	9.4	318.4	9.6
1600	9.7	321.3	9.9
1650	10.1	323.1	10.3
1700	10.2	323.6	10.4
1750	10.1	325.7	10.2
1800	10.6	326.5	10.7
1850	11.0	328.0	11.1
1900	11.5	329.8	11.6
1950	12.4	338.2	12.4
2000	12.5	336.9	12.5

TABLE 38. WIND PROFILES AT PILOT BALLOON SITES FOR 25 NOVEMBER, 1975
Vector Averages

	Central		Mesa		Goodyear		Grad School	
Height m	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees	Speed m/sec	Dir. Degrees
50	3.0	103.4	1.1	120.7	2.8	98.4	.5	130.4
100	3.5	109.6	1.8	136.7	3.3	107.0	1.0	129.8
150	2.7	122.0	2.2	156.4	3.0	117.2	1.2	131.3
200	2.0	132.6	2.1	157.4	2.4	126.7	1.8	140.1
250	1.7	138.5	1.8	149.8	1.9	136.9	2.4	149.8
300	1.4	103.4	1.8	150.6	1.5	147.8	2.2	156.9
350	.6	161.5	1.9	145.1	.9	157.2	1.7	176.8
400	.4	310.1	1.8	166.6	.7	147.4	1.2	213.7
450	1.1	307.0	1.6	163.7	.9	251.9	1.1	236.7
500	1.5	305.1	1.5	171.1	1.4	284.9	1.2	252.6
550	1.8	298.5	1.5	182.9	2.2	311.3	1.4	266.5
600	2.1	294.2	1.4	198.8	3.2	312.9	1.3	284.5
650	2.4	289.7	1.4	219.7	3.9	317.1	1.3	310.0
700	2.8	288.0	2.0	255.5	4.8	316.1	1.5	321.1
750	3.1	287.4	2.7	280.8	5.5	315.1	1.6	329.2
800	3.5	285.5	3.1	286.9	6.1	309.4	1.9	331.1
850	3.7	286.2	2.9	294.9	6.3	303.1	2.2	330.5
900	5.2	295.7	4.3	296.9	6.7	301.9	2.6	327.6
950	6.0	301.5	4.9	299.7	7.0	301.1	3.3	326.1
1000	6.2	298.9	5.0	293.6	7.7	301.2	4.2	320.0
1050	6.3	298.3	5.4	289.0	8.3	301.2	5.1	316.0
1100	6.6	302.3	6.0	293.0	8.8	301.5	6.1	313.7
1150	7.0	304.8	6.4	295.9	9.2	302.9	6.4	311.8
1200	7.5	305.8	6.7	298.1	9.2	304.2	7.2	311.5
1250	7.8	307.5	6.8	298.4	9.0	306.7	7.5	312.5
1300	8.0	309.4	6.9	298.0	8.7	309.9	8.1	313.1
1350	8.5	310.4	7.1	300.0	8.6	313.0	8.6	313.4
1400	9.2	312.2	7.4	302.2	8.3	316.8	9.0	314.2
1450	9.4	313.8	8.2	304.5	8.5	320.4	9.2	320.5
1500	9.5	310.6	8.9	306.4	8.8	323.3	9.3	325.3
1550	9.7	311.3	9.4	308.2	9.5	324.6	9.4	327.1
1600	10.3	314.0	9.0	309.2	10.1	326.3	9.8	328.9
1650	10.5	314.5	8.8	311.4	10.8	328.3	10.2	330.6
1700	10.3	316.6	8.2	313.1	11.0	328.6	11.5	330.3
1750	9.9	319.6	7.2	315.1	11.2	330.0	11.6	331.1
1800	10.3	322.0	7.7	317.8	11.7	331.8	12.7	329.4
1850	10.7	324.4	8.4	320.3	12.1	334.6	14.6	328.5
1900	11.1	327.7	8.9	323.9	13.0	335.3	14.3	328.0
1950	.0	.0	.0	.0	11.8	339.1	13.0	337.4
2000	.0	.0	.0	.0	12.3	336.9	12.7	336.8

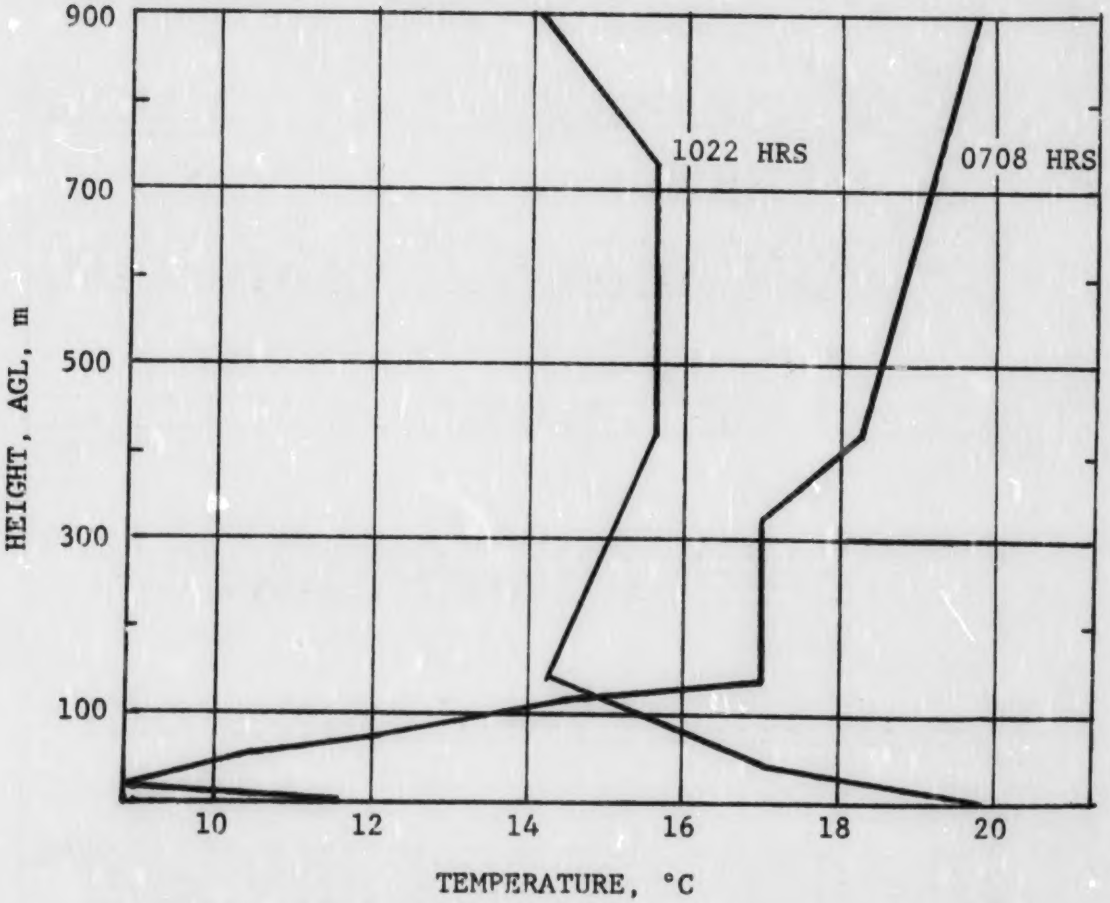

Figure 10. Height vs. Temperature, 25 November, 1975.

TABLE 39. CARBON MONOXIDE CONCENTRATIONS FOR 25 NOVEMBER, 1975

Hour	Station					
	9. Mesa	8. Scottsdale	1. Central	2. South	3. Capital	4. Glendale
0000	1.	4.	Not Functioning	3.	10.	1.
0200	3.	2.		3.	6.	1.
0400	1.	-		2.	6.	1.
0500	-	-		2.	2.	1.
0600	2.	3.		2.	2.	1.
0700	7.	7.		5.	3.	3.
0800	4.	4.		7.	5.	4.
0900	2.	2.		4.	4.	3.
1000	1.	2.		3.	5.	2.
1100	1.	1.		3.	3.	3.
1200	2.	-		2.	2.	2.

Data Courtesy of Maricopa County Telemetry Network

TABLE 40. HELICOPTER SAMPLING DATA FOR 25 NOVEMBER, 1975

Track	Time Start	min Δ	Altitude ft	Altitude m	Filter No.	Wt, μg	Flow, m^3	Conc, $\mu g/m^3$	Nephelometer, Volts ** (Position in Track) N		Midpoint		S	Average
East-Upwind														
11	0828	19	500	150	117550	44	11.83	3.7	1.2	⌒	1.7	—	1.3	1.4
11	0849	18	100	30	117534	(500)	11.21	(45.)	1.3	∿	2.7	3.5 ∧	1.3	1.8
11	1031	16	1000	305	117500	37	9.96	3.7	1.3	—	1.1	—	1.0	1.2
11	1051	17	100	30	117558	543	10.58	51.3	1.2	∧∧	1.7	∿	1.5	1.5
West-Downwind														
1	0719	15	500	150	117512	145	9.34	15.5	1.3	∿	1.6*	∿	1.3	1.4
1	0736	15	100	30	117527	232	9.34	24.8	1.2	∿	1.3	* ∿	1.5	1.3
1	0754	15	1800	550	117518	(37)	9.34	(4.)	1.1	—	1.1	—	1.1	1.1
1	1126	15	750	230	117553	(200)	9.34	(21.)	1.4	∿	2.0*	∿	1.3	1.6
1	1144	14	1500	457	117559	(<10)	8.72	(<1.1)	1.3	∿	1.2	—	1.1	1.2
2	1202	13	500	150	117556	1037	8.09	128.2	1.3	—	3.0*	∿	1.5	1.9

*Brown cloud

**The nephelometer responds to μm-sized particles, not to the full range of sizes collected by the samplers. The table shows the shape of the nephelometer trace and the average readings at ends and midpoint of each helicopter run.

( )Numbers in parentheses represent microscopical estimates of mass

west. There were reports of large forest fires in the Los Angeles region, for example. These runs resulted in low concentrations of 1 to 4 $\mu g/m^3$ based on microscopy estimates.

The last helicopter run was made over Glendale (Track 2) rather than Goodyear (Track 1) in case the polluted urban air mass was draining to the west so slowly that it might not have time to reach Track 1. This run measured a concentration of 128 $\mu g/m^3$ at 150 m height, and the nephelometer showed a hump of 3.0. Carbon monoxide levels from the County sampling network (Table 34) were also higher near Glendale in late morning than in early morning, indicating a drift of automobile-related pollutants.

Table 41 summarizes mass concentrations. Table 42 presents the mass flux results. The mass flux is higher upwind than downwind in the first 20 m, due to the influence of the high values recorded at Chandler. Above 20 m, the values are higher downwind.

MICROSCOPIC PARTICLE CHARACTERIZATIONS

Upwind Helicopter Samples

The Track 11 upwind samples contained primarily minerals and clay aggregates. Quartz, calcite, and mica together comprised half of the mineral populations. The clay aggregates were typical of those seen at the ground level sampling sites east of Phoenix. Fine carbonaceous material, most of which was tailpipe emissions, and recrystallized sulfate needles together comprised a major portion of most of the upwind samples. These latter two components were found to decrease with increasing altitude during the early morning samples. The later morning 30 m sample showed lower loadings of both materials, while the 305 m sample showed increased sulfate and decreased carbonaceous particle concentrations.

Particle size tended to decrease with increasing altitude. At the lower altitudes, the bulk of the sample mass was in the 15-25 μm particles. By 305 m, the 5-15 μm particles represented the bulk of the sample mass.

Downwind Helicopter Samples

The Track 1 downwind samples were composed of slightly different minerals than the upwind samples. In most samples, calcite concentrations were higher

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TABLE 41. MASS CONCENTRATIONS FOR 25 NOVEMBER, 1975

	Height m	Mass Concentrations, µg/m³												
		Hi-vol		Andersen*						Dichotomous *		Hi-vol (Microscope Est.**)		
		Tower	County	>25 µm	>15 µm	>8 µm	>2.5 µm	>0.9 µm	Sum	Fine <3.5µm	Coarse >3.5µm	>15 µm	5-15 µm	<5 µm
Upwind														
D. Indian Res.	3	238.			53.3	42.2	45.9	11.9	153.			95.	119.	24.
	10				27.8	6.4	51.6	17.9	104.					
	30			—	19.0	--	33.5	29.8	82.					
E. Mesa	3	228.			155.9	21.4	8.7	7.3	193.	44.	90.			
	10				39.4	20.9	28.4	8.1	97.					
	30			15.1	—	5.2	26.6	14.6	46.					
F. Chandler	3	510.												
	10		436.							66.	190.			
	30													
8. Scottsdale	8		258.							47.	123.	129.	103.	26.
14. Paradise Valley	2		494.											
Helicopter 0800 hrs	30	(45.)												
	150	3.7												
Helicopter 1000 hrs	30	51.3												
	305	3.7												
Downwind														
A. Am. Grad. School	3	277.6			57.2	30.8	58.3	9.6	156.			83.	153.	42.
	10				34.6	27.8	36.4	21.7	121.					
	30				28.9	11.4	19.6	14.6	75.					
B. Parker	3	192.		38.3	—	28.2	46.9	7.4	121.					
	10			29.8	—	15.0	39.0	18.4	102.					
	30				19.9	21.9	28.7	22.7	93.					
C. Page	3	228.			50.9	19.7	28.8	7.4	107.			114.	80.	34.
	10			30.7	—	19.5	26.4	20.4	97.					
	30				26.6	29.7	20.7	31.6	109.					
4. Glendale Coll.	8		283.											
5. West Phoenix	6		273.							45.	60.			
Helicopter 0800 hrs	30	24.8												
	150	15.5												
	550	(4.)												
Helicopter 1100 hrs	150	128.2												
	230	(21.)												
	457	(<1.1)												
Central														
1. Central Phoenix	10		132.									126.	126.	28.
3. Arizona Capitol	7		279.		126.	126.		28.						
2. South Phoenix	10		157.							65.	132.	63.	71.	24.

*Aerodynamic diameter size fractions
**Geometric diameter size fractions

( )Numbers in parentheses are microscopical estimates of mass

TABLE 42. MASS FLUX FOR 25 NOVEMBER, 1975

Height m	Conc. μg/m^3	Wind, m/sec	Mass Flux, mg/sec-m^2
Upwind			
0-6	279.	1.	.28*
6-20	204.	1.5	.31*
20-50	56.	1.7	.10
50-350	3.7	2.0	.01
Downwind			
0-6	180.	1.	.18
6-20	164.	1.5	.25
20-50	75.	1.7	.13
50-350	55.	2.0	.11
**			
500	2.5		
Central			
10	191.		

* High concentration at Chandler raises the average

** Inversion height

and mica concentrations were lower. Clay aggregates were of different composition than in the upwind samples (lower iron content) and were lower in concentration. Recrystallized sulfate needle concentrations were higher at all altitudes than comparable upwind samples. The relative sulfate concentration also increased with increasing altitude, but was generally lower in the later morning samples.

Concentrations of fine carbonaceous material (tailpipe emissions) and rubber tire dust tended to be lower in the early morning samples than the later morning. Concentrations of both materials decreased with increasing altitudes.

Overall, particle sizes were larger than the upwind samples.

Upwind (East) Hi-Vol Filter Samples

Site 14. Paradise Valley Pumping Station, 494 μg/m^3

This sample was identical in particle type composition to the sample of the 21st. The sample showed minerals and clays as the primary components, with a major contribution from automobiles.

The major difference between the 21st and 25th samples was particle size. The sample from the 25th showed smaller particle sizes due to fewer numbers of particles greater than 15 μm in size.

Site D. Indian Reservation, 238 μg/m^3

Small mineral particles and large clay aggregates were the primary sample components. Biological materials were present only in trace concentrations. Automobile emissions represented trace to minor sample components.

Particle size was fairly large. Approximately 50% of the sample mass was in particles greater than 15 μm. This larger particle size accounted for the increased mass concentration compared to the sample collected on the 21st.

In addition to the difference in particle size on the 25th, particle types were also different. Carbonaceous particle concentrations were lower while clay aggregate concentrations were significantly higher on the 25th vs. the 21st.

Site 8. Scottsdale, 258 $\mu g/m^3$

The sample was slightly different in particle type composition compared to the 21st. Higher concentrations of small clay aggregates were seen on the 25th. The particle size, therefore, was slightly smaller than on the 21st. The bulk of the sample mass was in the 5-15 μm particles. As with the 21st sample, automobile emissions were a major sample component.

Site E. Mesa, 228 $\mu g/m^3$

The sample was essentially identical in composition and particle size to the one collected on the 21st -- i.e., minerals were the primary materials with major contribution from automobiles. Increased loadings of all materials resulted in the higher mass concentration.

Site F. Chandler, 510 $\mu g/m^3$

The sample was slightly different than the sample collected on the 21st. Slightly higher concentrations of automobile emissions (mostly rubber tire) were seen. The primary components were still the minerals and clay aggregates. The large numbers of biological particles -- especially the trichomes and cornstarch grains -- were again present.

Site 16. Chandler, 436 $\mu g/m^3$

Except for particle size and slightly higher clay concentrations, the sample from the 25th was identical in composition to the 21st sample. The particles still tended to be larger than those seen at the F Chandler site.

Downwind (West) Hi-Vol Filter Samples

Site A. American Graduate School, 278 $\mu g/m^3$

The sample was identical to the sample collected on the 21st as to particle types and their concentrations. The sample was primarily minerals and clay aggregates with minor contributions to the sample mass by automobile emissions. Fewer particles of all types, especially in the greater than 15 μm range, resulted in the lower mass loading compared to the 21st.

Site 4. Glendale Community College, 283 $\mu g/m^3$

The sample was composed primarily of small mineral particles. Clay aggregates were a major sample component. Automobile emissions were a minor to major sample component.

In addition to the lower concentration of automobile emissions, mineral particle sizes were larger compared to the sample collected on the 21st. The increased numbers and sizes of the mineral particles accounted for the increased mass concentration for the 25th.

Site B. Parker, 192 $\mu g/m^3$

The sample was identical to the one collected on the 21st. Small mineral particles were the primary components with clay aggregates and automobile emissions each contributing major portions of the sample mass.

Site 5. West Phoenix, 278 $\mu g/m^3$

This was the only downwind sample to show a change in composition from the sample collected on the 21st. Although mass loadings for the two days were equivalent, the 25th sample contained approximately 20% by mass of carbonaceous material (from automobile emissions) vs. the 40% seen on the 21st sample.

Quartz, feldspars, and mica particles were the primary components. Particle sizes were quite large, as was the case on the 21st. Approximately 60% of the sample mass was contained in particles greater than 25 μm.

Site C. Page Residence, 228 $\mu g/m^3$

The sample was identical in composition to that of the 21st. Minerals and clay aggregates were the primary particle types. Automobile emissions made minor contributions to the sample mass. Fewer particles of all types resulted in the lower mass concentration for this sample compared to the 21st.

Central Hi-Vol Filter Samples

Site 1. Central Phoenix, 133 $\mu g/m^3$

This sample was also identical in composition to the sample collected on the 21st. Feldspars and quartz were the primary sample components. Automobile emissions were major contributors to the sample mass.

Site 3. Arizona State Capitol, 279 $\mu g/m^3$

The sample was composed primarily of large quartz, feldspar, and mica particles. Automobile emissions (mostly huge rubber tire particles) were major sample components.

Compared to the 21st, tailpipe emissions were lower in concentration, while rubber tire dust concentrations were higher due to larger particle sizes.

Site 2. South Phoenix, 157 $\mu g/m^3$

Except for slightly larger particle sizes on the 25th, the sample was identical in composition to the sample collected on the 21st. Mineral particles were the primary components with automobile emissions making a major contribution to the sample mass.

ELEMENTAL ANALYSES

Tables 43 and 44 present elemental concentrations, as determined by x-ray fluorescence, for the dichotomous samples and Andersen final filters, respectively.

TABLE 43. X-RAY FLUORESCENCE ANALYSES OF DICHOTOMOUS SAMPLES FOR 25 NOVEMBER, 1975
Mass Percent

Sampling Sites	Stages*	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb	Sum
Upwind																											
D. Indian Res. 3 m																											
E. Mesa 3 m	F		3.4		4.0		.67	1.3					1.1			.10	.22	.29		1.0						3.1	15.
	C	2.4	12.4		0.6		1.4	4.8	.4				3.0			.10	.03	.03		0.11		.03				0.15	26.
F. Chandler 3 m (Tower) 10 m (County)	F	2.1	8.5		2.2		1.5	2.0	.13				2.2			.20	.06	.14		0.74						2.0	22.
	C	2.9	10.7	.12	.38	.14	1.4	2.9	.20			.04	2.8			.05	.02	.01		0.05	.01	.02				0.08	22.
8. Scottsdale 8 m	F		4.6		1.7	.29	.79	2.1					1.3			.11	.06	.24		2.1						5.5	19.
	C	2.0	9.5		0.4		1.2	4.8	.17				2.4	.03		.04		.03		.17		.04				.4	21.
14. Paradise Valley 2 m																											
Downwind																											
A. Am. Grad. School 3 m																											
B. Parker 3 m																											
C. Page 3 m																											
4. Glendale Coll. 8 m																											
5. West Phoenix 6 m	F		1.7		1.9	.21	.39	.53					0.7				.30	.27		.22						6.0	14.
	C	3.5	13.8		0.5	.32	1.4	3.9	0.2				3.6			.06	.08	.06		.33		.04				.68	28.
Central																											
1. Central Phoenix 10 m																											
3. Arizona Capitol 7 m																											
2. South Phoenix 10 m	F		4.4		1.5	.15	.84	1.4					1.9			.13	.81	.19		1.2						3.4	16.
	C	2.7	12.8		.45	.10	1.4	4.3	0.3			.05	3.5	.04			.08	.03		.12		.04				0.2	26.

*F=Fine Filter (<3.5 μm particles)
C=Coarse Filter (>3.5 μm particles)

TABLE 44. X-RAY FLUORESCENCE ANALYSES OF ANDERSEN FINAL FILTERS FOR 25 NOVEMBER, 1975

(Concentration, $\mu g/m^3$)

Site	Height m	Al	Si	P	S	Cl	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pt	Au	Hg	Pb
Grad School	3												.08							.19						.56
	10																			.13						.44
	30												.08							.04						.19
Parker	3																.02			.45						1.2
	10																	.03		.34						.96
	30																.04	.02		.29						.96
Page	3																.03			.04						.26
	10							.10					.07							.02						.13
	30						.11	.13					.20				.04			.04						.23
Indian Res.	3												.07				.03			.04						.27
	10												.05			.03				.03						.17
	30												.24			.10				.04						.31
Mesa	3				.35		.06						.15			.05	.03	.04		.27						.92
	10				.19								.06			.05	.03			.18						.74
	30				.21											.06	.04			.11						.57

SECTION 12

DISCUSSION OF MASS DATA

Before examining the trends in the mass data, it will be helpful to examine the data for internal consistency. There was some redundancy in the sampling, which allows internal comparisons.

COMPARISON OF VARIOUS SAMPLERS

Three different types of samplers were used at the 3 m sampling height; the mean concentration values determined by each type can be compared. The Chandler and Central sites were excluded from the following comparison because they are compared later.

	Hi-Vol	Andersen	Dichotomous
Mean, $\mu g/m^3$	203	122	172
Number of Samples	24	19	5

In general, the Andersen samplers gave lower mass concentration values than the hi-vol sampler. This result is partly due to the fact that the Andersen final filter weight was not determined. The mass concentrations measured with the Andersen samplers do not include aerosols with diameters less than 0.9 μm. The dichotomous sampler values agreed quite well with the hi-vol data.

SPECIAL CONSIDERATION OF CHANDLER SAMPLINGS

The mean concentration values obtained from hi-vol samplers at Chandler and at all other sites were significantly different:

	Chandler 3 and 10 m	All Other Sites 3 m
Concentration, μg/m^3	431	203
Number of Samples	10	24

The results which follow indicate that this represents a real difference and not an artifact of the sampling conditions. There were actually two sites at Chandler. One was a tower site, located in an unpaved maintenance yard, having a hi-vol at 3 m as well as Battelle samplers at 3, 10, and 30 m. The other site was the County site, located at 10 m on top of the police station, 2 blocks north of the tower site. The roads surrounding the police station were paved, and the surrounding ground was grassy. The County site had a hi-vol sampler; a dichotomous sampler was also installed there. The hi-vol data at the two sites are as follows:

	Hi-Vol, County 10 m	Hi-Vol, Tower 3 m
Concentration, μg/m^3	423	441
Number of Samples	5	5

The difference in mean values is slight, and could have been due to the difference in height. Therefore, it appears that the high values at the tower site were not due to dust stirred up by occasional maintenance trucks in the unpaved yard. Furthermore, if the yard were the source of the dust, the County site would have shown high values only when the wind was from the South, and this was not the case. Instead, it appears that the atmospheric particulate concentrations were generally high in the area near the two sampling sites, and the source must cover an area that is large compared to the two blocks distance between the sites.

Comparison of the hi-vol and dichotomous sampler data at Chandler results in only fair agreement; regardless, the dichotomous sampler mass concentration values are higher at Chandler than at all other sites.

	Hi-Vol 3 m and 10 m	Dichotomous 10 m
Concentration, $\mu g/m^3$	431	256
Number of Samples	10	6

Microscopic analyses have determined that the Chandler samples do not contain any new contaminants, but simply contain higher concentrations of the mineral matter which makes up the bulk of most samples from all sites. Clearly, there is something special about Chandler, but it is special in amount, not in kind.

Chandler represents a small city that is less developed than the cities of Mesa and Phoenix; fewer roads are paved, and more of the yards have bare ground. The higher dust levels may result from the concentration of activity on these areas of bare ground, such as driving on unpaved shoulders. The dust could be of agricultural origin, since Chandler is surrounded by a large irrigated agricultural area. Helicopter nephelometer traces frequently showed strong peaks when passing over the region near Chandler, although these peaks were not necessarily associated with the city of Chandler itself. However, microscopic analyses of Chandler samples did not reveal unusually large concentrations of biological materials or fertilizer particles, which would be associated with heavy agricultural activity. Undoubtedly, both types of activities -- automobile traffic and agriculture -- are responsible for the high TSP levels around Chandler.

CENTRAL PHOENIX SITES

The central city average mass concentration values at the 10 m sampling height are as follows:

	Hi-Vol	Dichotomous
Concentration, $\mu g/m^3$	210	222

These values are only slightly higher than the concentrations outside the city (excepting Chandler). However, the Central samples had a composition that reflected more automobile-related pollutants compared to mineral matter.

COMPARISON OF SAMPLING DAYS

Table 45 summarizes the mass loadings in relation to wind speed and direction on each sampling day. Generally, the mass concentration decreases with height and is greater downwind than upwind of the city, except on days when wind was from the east (21 Nov. and 25 Nov.). On these days, Chandler was upwind of the city of Phoenix, and the Chandler data raised the upwind average (starred values in the table).

Comparison of 17 Nov. with 18 Nov. shows that the mass concentrations are similar, even though the wind speed was higher on 18 Nov. than 17 Nov. (5 compared to 1 m/sec). As a result, the mass flux was higher on 18 Nov.

Wind conditions were similar on the two days when sampling was done in the morning (21 and 25 Nov.). The only difference was a somewhat higher inversion level on 25 Nov. The measured mass concentrations and fluxes on these two days were also similar at the lower two heights. The concentration was higher (greater than 60 $\mu g/m^3$) in the afternoon samplings at heights above 50 m. The mass flux at the higher altitude samplings showed more effect of wind speed, reflecting the influence of wind mixing to carry the particles to greater heights. The mass flux was 0.09 to 0.15 $mg/sec\text{-}m^2$ at 20-50 m on all days except 18 Nov., when it was 0.48 to 0.67 $mg/sec\text{-}m^2$.

The measurements made at night on 23-24 Nov. average somewhat lower (80 to 149 $\mu g/m^3$ up to 20 m height) compared to day samplings which average around 200 $\mu g/m^3$. Concentrations at greater heights were even lower (44 to 62 $\mu g/m^3$ at 20-50 m, and 20 $\mu g/m^3$ above the inversion height of 150 m). The lower particulate concentrations at night are probably due to decreased human activities at night. The samples from the central city also show a higher proportion of carbonaceous materials and lead from automobiles, compared to the mineral content.

TABLE 45. SUMMARIES OF MASS CONCENTRATION AND WIND DATA

		Wind		Concentration, $\mu g/m^3$			Mass Flux, $mg/sec\text{-}m^2$	
Date/Hr.	Height, m	Speed m/sec	Dir. Degrees	Upwind	Downwind	Central	Upwind	Downwind
Nov. 17 PM								
	0-6	1.	245.	199.	318.		.20	.32
	6-20	1.	245.	175.	320.	176.	.18	.32
	20-50	1.1	243.	75.	134.		.09	.15
Nov. 18 PM								
	0-6	5.	244.	186.	222.		.93	1.11
	6-20	5.	245.	138.	310.	294.	.69	1.55
	20-50	6.	245.	80.	112.		.48	.67
Nov. 21 AM								
	0-6	1.	60.	242.	228.		.24*	.23
	6-20	1.	90.	175.	133.	243.	.18*	.13
	20-50	1.6	105.	91.	94.		.15	.15
Nov. 22 PM								
	30	4.	90.	26.	(31.)		.10	(.12)
Nov. 23-4 Night								
	0-6	1.	100.	81.	149.	(105.)	.08	.15
	6-20	2.	50.	82.	140.	132.	.16	.28
	20-50	3.	50.	44.	(62.)		.13	(.19)
Nov. 25 AM								
	0-6	1.	85.	279.	180.		.28*	.18
	6-20	1.5	90.	204.	164.	191.	.31*	.25
	20-50	1.7	100.	56.	75.		.10	.13

*Chandler raised the average

( )Numbers in parentheses represent microscopical estimates of mass

OVERALL RESULTS

Mass concentrations generally exceed 75 $\mu g/m^3$ both upwind and downwind of the city of Phoenix. The downwind data tend to be higher, but this is obscured by the generally higher readings at Chandler, which may be either upwind or downwind of Phoenix.

SECTION 13

DISCUSSION OF MICROSCOPIC ANALYSES

For every sample analyzed by optical microscopy, a data sheet detailing estimated mass concentrations and size of individual particle types was prepared. These original data sheets have been compiled as an appendix to IITRI Report No. C6333C05-2. Concentration data for key sample components have been abstracted and are graphically displayed in Figures 11-15.

Soil components -- minerals, clays, and humus -- comprised at least 65% of the mass on all aerosol samples collected, except for one sample -- the 21 November West Phoenix sample. Automobile emissions -- fine carbonaceous tailpipe emissions and rubber tire dust -- were the next most massive sample component. Agriculture related emissions -- cotton fibers, cornstarch grains, shredded plant tissue, and fertilizer particles -- together with other biological particles related to general ground cover vegetation such as trees and grass -- spores, spore cages, pollens, trichomes -- represented only trace components on all samples both on mass and number bases. Combustion related emissions -- fly ash, charred paper and wood fragments, oil soot, and coal fragments -- from such sources as incinerators, heating plants, and power plants represented trace to minor components in some samples.

To aid in tracing mineral particle types seen on the filter samples to specific sources, soil samples from the western and eastern Phoenix sampling areas and bits of street pavement from the central Phoenix area were collected for optical microscopy analysis. The western Phoenix soil samples showed increased concentration of calcite and mica compared to the eastern soil samples. The clays and feldspars in the eastern soil were richer in iron compared to the western soil samples. More discrete iron oxide particles (hematite and magnetite) were also present in the eastern soil compared to

KEY TO FIGURES 11-15

Sampling Sites

West (Upwind of Phoenix on 17 and 18 Nov.)

A. American Graduate School
B. Parker Residence
C. Page Residence
4. West Phoenix
5. Glendale Community College

Central Sites

1. Central Phoenix
2. South Phoenix
3. Arizona State Capitol

East (Upwind of Phoenix on 21 and 25 Nov.)

D. Indian Reservation
E. Mesa (Tower)
9. Mesa (County)
8. Scottsdale Fire Station
F. Chandler (Tower)
16. Chandler (County)
14. Paradise Valley

Concentrations

P = >25% by mass
M = 5-25% by mass
m = 0.5-5% by mass

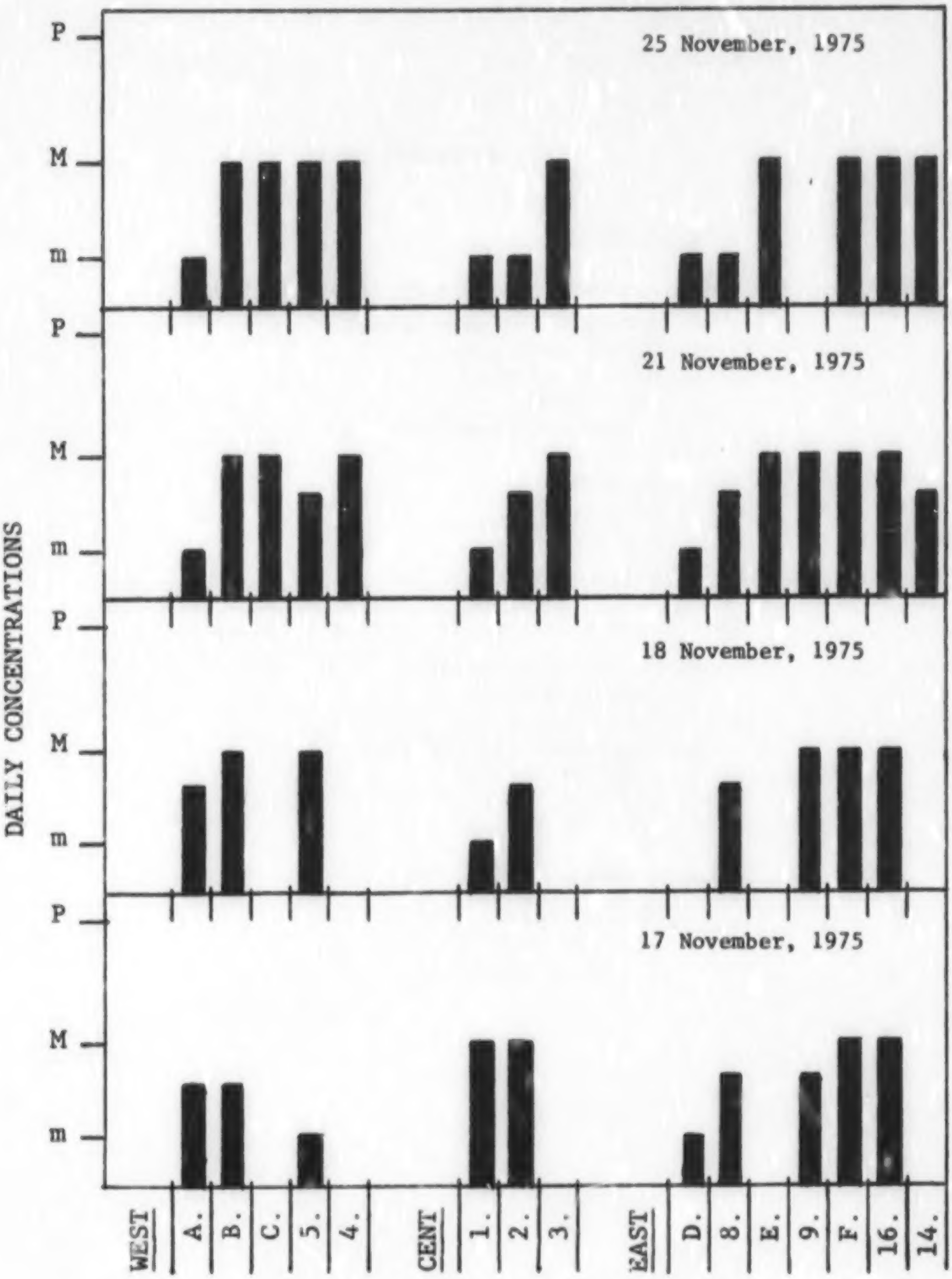

Figure 11. Calcite Mass Concentrations on Hi-Vol Filters.

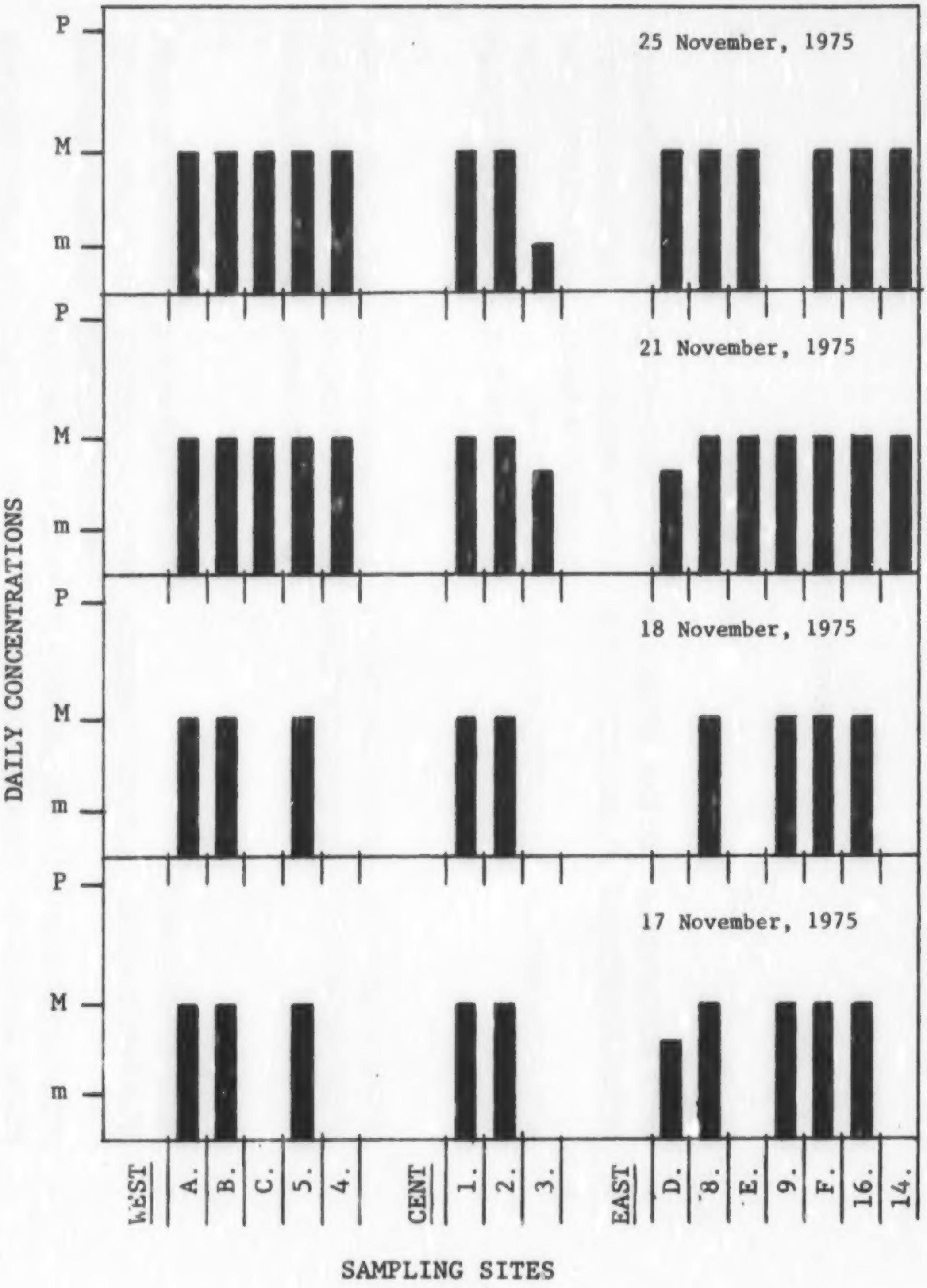

Figure 12. Mica Mass Concentrations on Hi-Vol Filters.

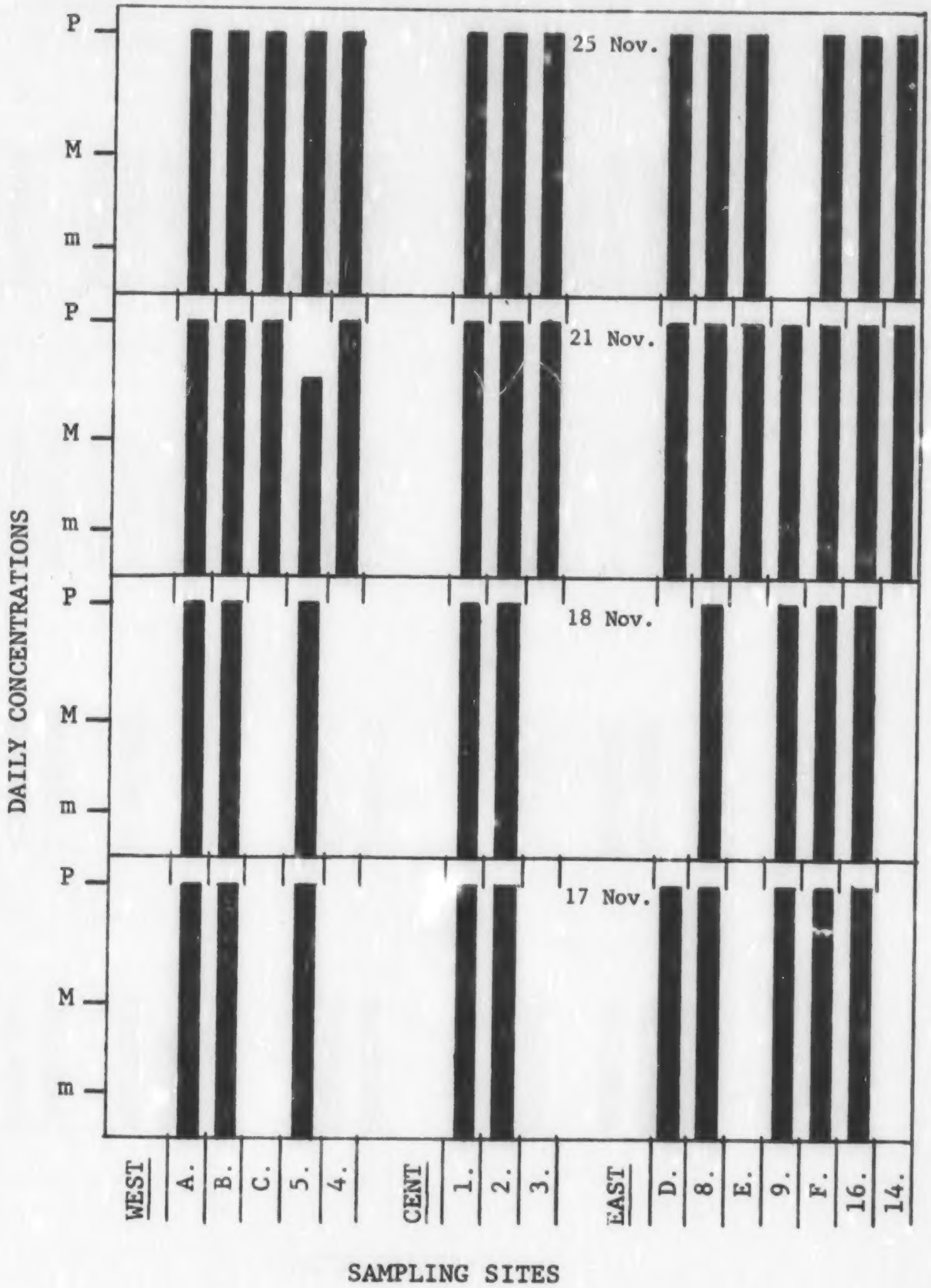

Figure 13. Other Minerals Mass Concentrations on Hi-Vol Filters.

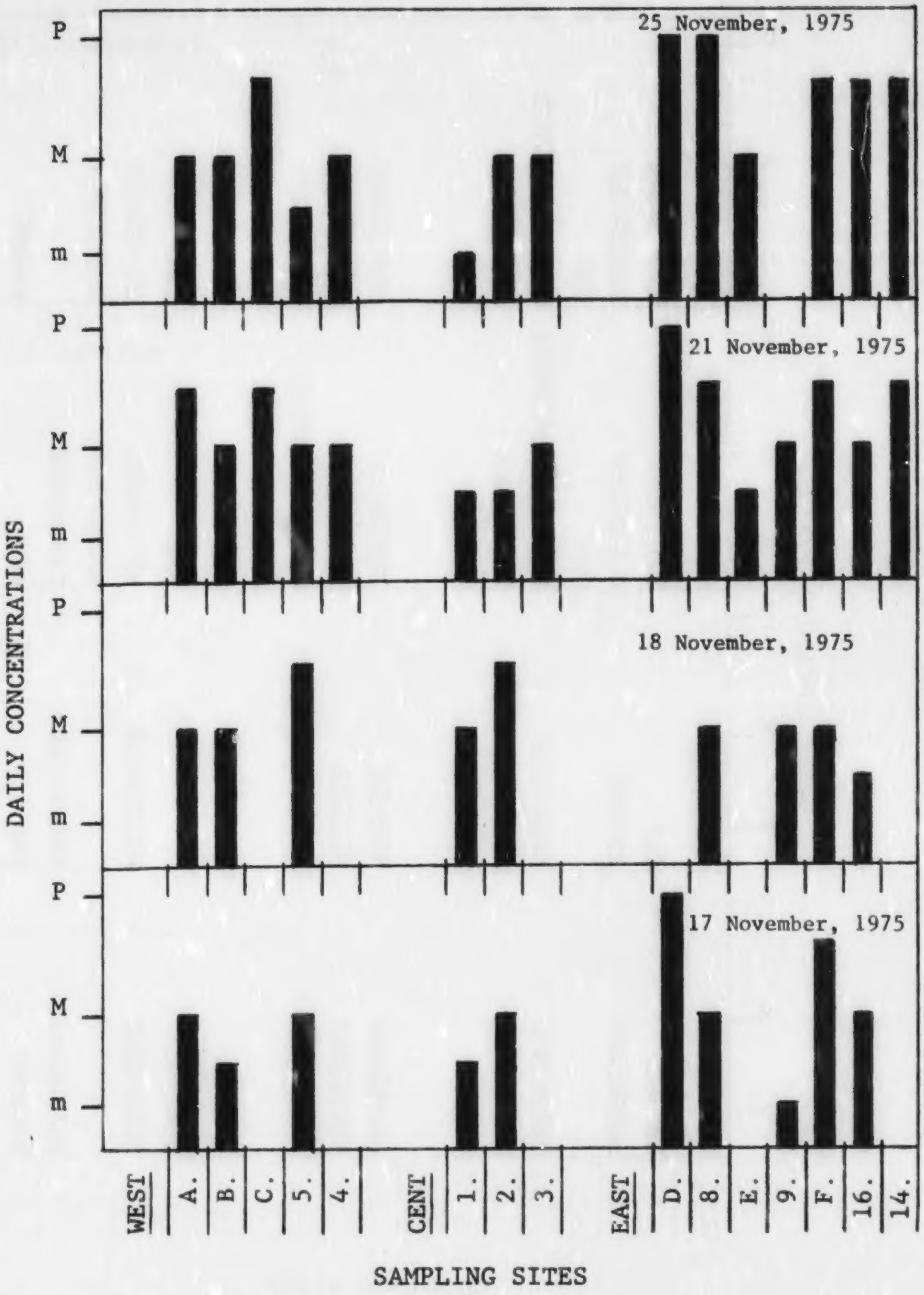

Figure 14. Clay Mass Concentrations on Hi-Vol Filters.

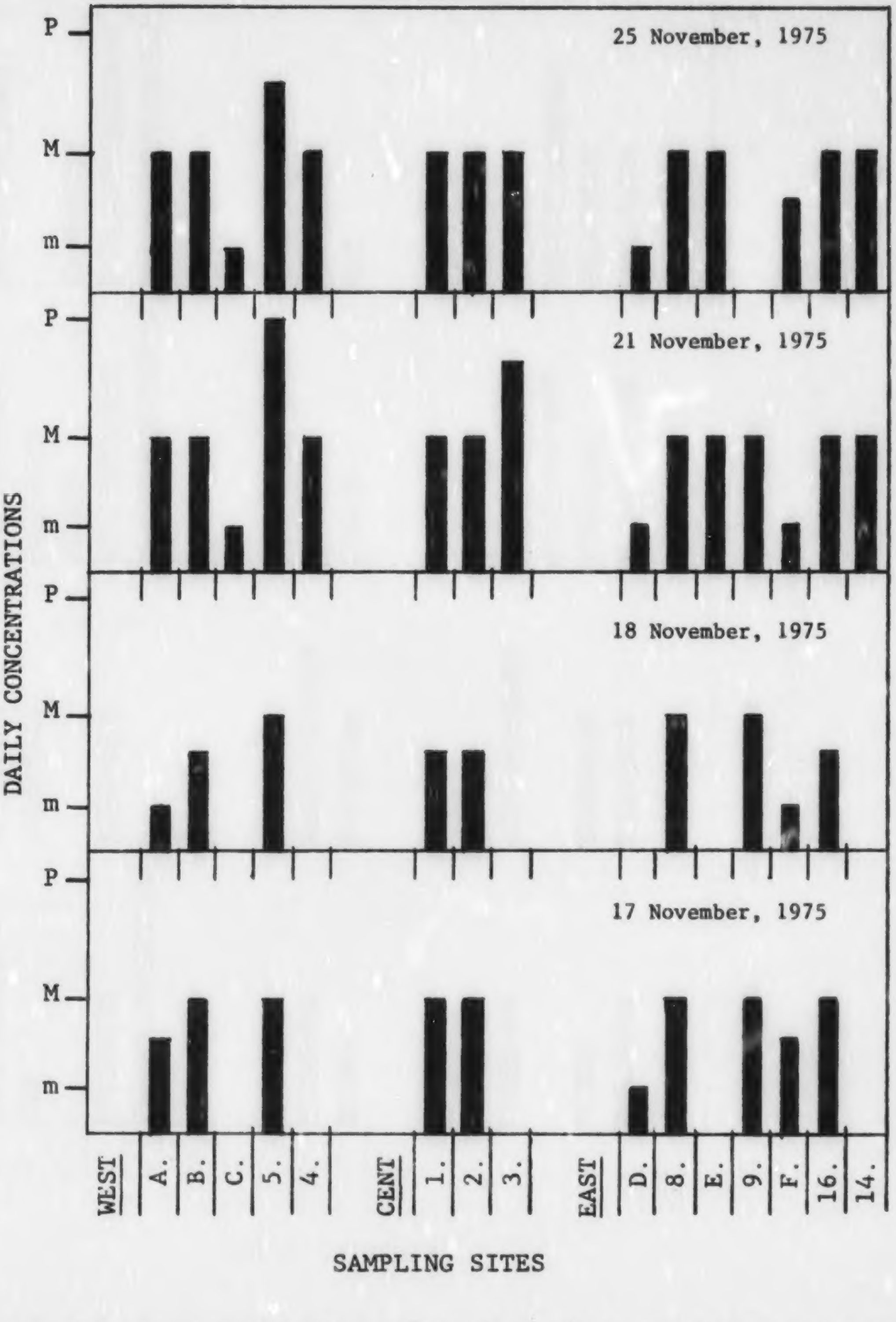

Figure 15. Automobile-Related Particle Mass Concentrations on Hi-Vol Filters.

the western soil. The minerals in the street pavement aggregate were three of the primary minerals found in the Phoenix area soil -- calcite, quartz, and orthoclase (a feldspar).

In general, particles collected at each sampling site were representative of the terrain surrounding the sampling site. Each sampling site showed influences of relatively localized sources, particularly nearby highways, streets, roads, and driveways. For the most part, western site filter samples contained mineral particle types found in the western soil samples, while eastern site filter samples contained minerals indigenous to the eastern soil, regardless of wind direction during the sampling period. The central Phoenix sites tended to contain particle types more common to the western Phoenix area, even when the wind was from an easterly direction. The only date on which significant increases of particle types common to one side of the Phoenix area occurred in samples collected on the opposite side of Phoenix was 18 November, when the wind speed increased to 5 m/sec. On this date, the eastern Phoenix samples showed increases in calcite and mica, which are more common to the western Phoenix area.

The particle types and morphologies present in the samples do point to specific sources for the suspended particles in Phoenix and also give some indication of the relative contributions of the various sources.

Vehicular traffic (other than agricultural vehicles) has to be considered as the prime generator of suspended particulate matter. The appearance of smooth-surfaced, worm-shaped rubber tire particles, fine carbonaceous particles (tailpipe emissions), and clean-surfaced, sharp, angular mineral fragments indicate vehicle travel over paved roadways. This combination of particle types and morphologies was most frequently seen in samples from the central Phoenix area, as one might expect. Torn, rough-surfaced rubber tire particles and the fine carbonaceous particles, together with the more rounded, clay-coated minerals, indicate vehicle travel over unpaved roads and shoulders.

Obviously, wind activities do account for suspension of some of the more rounded, clay-coated minerals found in the Phoenix samples. However, particle sizes and morphologies of the majority of mineral particles found in all the Phoenix samples were not typical of wind-eroded materials. Particle surfaces should have been more frosted, indicating tumbling and collision with finer particles; rather, particle surfaces tended to be gouged, scratched, with fine particles embedded, suggesting mechanical wear. Another indication that wind is not the primary source for suspension of particles is the fact that mass concentrations at most sampling sites were not significantly elevated on 18 Nov. when the wind speed increased to 5 m/sec, compared to the other sampling days when wind speeds averaged 1 m/sec (Table 46). The wind's primary role in the TSP problem of Phoenix is probably to maintain particles in suspension over the city by moving them back and forth, rather than blowing them completely out of the area.

Agricultural activity cannot be ruled out as a major generator of suspended particles. It is rather difficult to determine if all clay-coated, round-edged minerals were suspended by automobile tires or tractor plows. The presence of cotton fibers, and especially fertilizer particles, in some samples definitely indicate contributions to mass loadings by agricultural activity. However, the few numbers of cotton fibers and shredded plant stems, and the occasional appearance of few fertilizer particles suggest that agricultural activity is not as an important generator of suspended particles as vehicular traffic.

TABLE 46. AEROSOL MASS CONCENTRATIONS ON HI-VOL FILTER SAMPLES

	$\mu g/m^3$				
	17 Nov.	18 Nov.	21 Nov.	23-4 Nov.	25 Nov.
	West Wind	West Wind	East Wind	North Wind	East Wind
WEST SITES					
A. Amer. Grad. School	216	211	373	109	278
B. Parker Residence	214	164	182	156	192
C. Page Residence	-	-	305	151	228
5. West Phoenix	239	384	263	134	278
4. Glendale Com. Coll.	-	-	245	111	283
EAST SITES					
D. Indian Reservation	407	-	182	129	238
8. Scottsdale	221	441	179	142	258
9. Mesa (County)	157	209	156	56	-
E. Mesa (Tower)	-	-	178	70	228
16. Chandler (County)	485	439	490	263	436
F. Chandler (Tower)	552	474	433	234	510
14. Paradise Valley	-	-	433	128	494
CENTRAL SITES					
1. Central Phoenix	112	287	108	162	133
2. South Phoenix	206	257	315	116	157
3. Arizona Capitol	-	-	394	194	279

SECTION 14

DISCUSSION OF ELEMENTAL ANALYSIS DATA

The x-ray fluorescence analysis data of the dichotomous and Andersen final filter samples were presented in tables in Sections 7-12 of this report. Concentration data of selected elements obtained from both types of samplers have been regrouped for comparison purposes and appear in Tables 47-51. It is not surprising that the individual elemental concentrations do not correlate well between the two types of samplers. Particle size differences between the two types of samplers account for the poor correlation. However, the important observation to be made from these tables is that both types of samplers tend to show increased concentrations of urban related pollutants -- specifically lead and bromine -- in the downwind vs. upwind samples. The values are generally about twice as high downwind as upwind, pointing to a source in the metropolitan area such as automobiles. The highest values of bromine (1 to 2 $\mu g/m^3$) and of lead (4 to 8 $\mu g/m^3$) were observed on 21 and 5 Nov., when sampling was done in the morning, and on 23 and 24 Nov., when sampling was done at night. This is believed to be related to the inversion at night and morning, trapping automobile pollutants. These trends can be correlated with the measurements of carbon monoxide concentrations shown in tables in Sections 8, 10, and 11. Carbon monoxide is also an indicator of automobile emissions.

Copper, zinc, and arsenic were present on each sampling day in slightly higher concentrations downwind of Phoenix compared to upwind. The differences in concentration were not sufficient to determine if Phoenix was the source of these elements. Although the wind was not from the direction of the copper smelters (located south of Phoenix) on any of the sampling days, it is suspected that mixing of air masses introduced smelter emissions into the Phoenix area. Micro x-ray elemental analyses performed on individual particles

TABLE 47. X-RAY FLUORESCENCE ANALYSES SUMMARY FOR 17 NOVEMBER, 1975
(Wind 1 m/sec, 245°)
Concentration, μg/m³

	Andersen Final Filters		Dichotomous Samplers*		
Element	Upwind	Downwind	Upwind	Central	Downwind
Fe	.2	.2	.8/4	.8/4	1/3
Cu	.1	.1	/.1	/.03	.1/.2
Zn	.05	.1	.06/.2	.1/.1	.1/.2
As	.03	.1	.1/.05	.2/.05	.4/.05
Br	.15	.3	.6/.1	.4/.1	.8/.1
Pb	.7	1.0	2/.2	1/.05	3/.3

*Fine Filter (<3.5 μm particles)/Coarse filter (>3.5 μm particles)

TABLE 48. X-RAY FLUORESCENCE ANALYSES SUMMARY FOR 18 NOVEMBER, 1975
(Wind 6 m/sec, 245°)
Concentration, μg/m^3

	Andersen Final Filters		Dichotomous Samplers*		
Element	Upwind	Downwind	Upwind	Central	Downwind
Fe	.3	.3	1/5	2/3	2/3
Cu	.05	.05			
Zn	.03	.05	/.05	/.03	/.05
As			.1/.01	.1/.01	.03/.01
Br	.02	.05	.6/.1	.3/.03	.1/.05
Pb	.15	.25	1/.04	.8/	.2/.1

*Fine filter (<3.5 μm particles)/Coarse filter (>3.5 μm particles)

TABLE 49. X-RAY FLUORESCENCE ANALYSES SUMMARY FOR 21 NOVEMBER, 1975
(Wind 1 m/sec, 90°; 3 m/sec, 350° above 700 m)
Concentration, μg/m³

	Andersen Final Filters		Dichotomous Samplers*	
Element	Upwind	Downwind	Upwind	Central
Fe	.3	.3	2/3	2/4
Cu	.05	.03	.1/.05	/.03
Zn	.05	.05	.1/.05	.3/.02
As	.05	.05	.2/.03	.05/.04
Br	.3	.3	.5/.05	1/.2
Pb	.4	.8	2/.1	4/.3

*Fine filter (<3.5 μm particles)/Coarse filter (>3.5 μm particles)

TABLE 50. X-RAY FLUORESCENCE ANALYSES SUMMARY FOR 23-24 NOVEMBER, 1975
(Wind 1 m/sec, 70°; 4 m/sec, 45° above 50 m)
Concentration, μg/m^3

	Andersen Final Filters		Dichotomous Samplers*		
Element	Upwind	Downwind	Upwind	Central	Downwind
Fe	.15	.3	1/3	.8/.3	1/3
Cu	.04	.04			
Zn		.04		.05/.2	.05/.05
As		.02	.1/.02	.2/.03	.2/.04
Br	.05	.3	1/.1	2/.2	2/.2
Pb	.25	.8	2/.3	6/.7	5/.3

*Fine filter (<3.5 μm particles)/Coarse filter (>3.5 μm particles)

TABLE 51. X-RAY FLUORESCENCE ANALYSES SUMMARY FOR 25 NOVEMBER, 1975
(Wind 1 m/sec, 85°; 2 m/sec, 300° above 450 m)
Concentration, $\mu g/m^3$

	Andersen Final Filters		Dichotomous Samplers*		
Element	Upwind	Downwind	Upwind	Central	Downwind
Fe	.2	.1	1.5/2.5	2/3.5	1/3.6
Cu	.06		.15/.05	.13/	/.06
Zn	.03	.03	.1/.03	.8/.1	.3/.1
As	.04	.03	.25/.03	.2/.03	.3/.06
Br	.03	.3	1.5/.1	1/.1	.2/.3
Pb	.3	.9	4/.2	3/.2	6/.7

*Fine filter (<3.5 μm particles)/Coarse filter (>3.5 μm particles)

through the scanning electron microscope revealed discrete lead-sulfur, bismuth-sulfur, and copper-sulfur containing particles. These particles were of a size and morphology typical of smelter emissions.

For both the Andersen and dichotomous samples, iron concentrations were very similar at the downwind compared to the upwind sites on all sampling days. Although the minerals and clays of the eastern Phoenix area soils are richer in iron, compared to the soils of western Phoenix, major differences in upwind/downwind iron concentrations probably did not appear due to the many other sources of iron in the Phoenix urban area.

The detailed data for x-ray measurements from Andersen final filters were given in Tables 8, 15, 23, 36, and 44. These tables show that there is a slight decrease in lead and bromine concentrations with height, which may be expected since only the finest fraction is being analyzed in this case. Perhaps of more significance is to notice the difference between the Indian Reservation site and Mesa when both are upwind as on 21 Nov. and 25 Nov. The Mesa site has five times more bromine and three times more lead. This should not be surprising since Mesa is a city of 100,000 people, with heavy automobile traffic, while the Indian Reservation site was close to the north-east edge of the irrigated agricultural area, bordering on unsettled desert. In other words, the Indian reservation is more truly an upwind site than Mesa. During the night sampling of 23-24 Nov., both Mesa and the Indian Reservation sites were low (0.05 and 0.25 $\mu g/m^3$) in bromine and lead, respectively, indicating that either that night automobile traffic is slight in the Mesa area, or that the different wind direction (NE instead of E) caused the Mesa site to be truly upwind on 23-24 Nov.

TABLE 52. CONVERSION TABLE TO S.I. UNITS

To Convert From	To	Multiply By
mile	meter	1.609 344*E+03
foot	meter	3.048 000*E-01
hour	second	3.600 000*E+03
minute	second	6.000 000*E+01
gram	kilogram	1.000 000*E-03
degree	radian	1.745 329 E-02
liter	meter^3	1.000 000*E-03